VITAMINES

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ESSENTIAL FOOD FACTORS

BY

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TO

C. S. H.

AND

M. H.

PREFACE

This book is a popular presentation of a subject which concerns every one of us; for vitamines are substances, as yet ill-defined, whose presence in food is essential to our well-being: *their absence makes life impossible.* And what more pressing problem to-day than that of food!

The entire subject is not more than ten years old—we ate vitamines before 1910, but we were not aware of it—yet the mass of work that has been done during these few years has added enormously to our knowledge of the science of nutrition. But the results of such research work are securely hidden from the gaze of the layman by their publication in technical journals, and through the use of language which is well-nigh meaningless to the man who is not a food specialist. The aim of the present volume is to reinterpret, in terms of our everyday tongue, the language of the research worker. Though "popular," the book is, I believe, a very faithful account of the labors of our scientific friends.

Experience has taught me that by far the best method of approach to an entirely new subject is the historical or evolutionary. The reasons for each successive step in the process of reasoning

and experimentation then become clear. That is why I have devoted the first part of the book to a survey of nutrition *prior* to the time when vitamines were introduced.

The summary will, I trust, be found to be a convenient brief review of the entire subject.

The bibliography has been prepared to satisfy those readers whose appetites I have whetted.

My thanks are due to Professor W. J. Gies (Columbia), Colonel W. P. Chamberlain (Medical Corps, U. S. A.), Dr. Casimir Funk (H. A. Metz & Co.), Dr. Arthur Harden (Lister Institute, London), Professor E. V. McCollum (Johns Hopkins), Professor L. B. Mendel (Yale), Dr. E. G. Miller, Jr. (Columbia) and Dr. T. B. Osborne (Connecticut Experimental Station). These gentlemen have helped me in a number of ways.

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CHAPTER I

INTRODUCTION

You burn a piece of wood or coal to get heat; but what makes your body hotter than the air outside? Why, when the doctor thrusts a thermometer into you, does the instrument register a temperature of 98—and sometimes a few degrees higher, if you have the "flu" for example—though the temperature of the room is much lower? Is your inside an imitation of a fireplace? Even if it is, the source of heat is certainly neither coal, nor wood, nor paper, nor anything else that is commonly used as fuel.

Such questions have agitated the minds of thinking men from the remotest times, but only within the last century or so have satisfactory answers been found. The guess that the body had certain analogies to a furnace was a good one; but before we could solve the riddle of the body furnace, we had to acquire clearer notions of just what this "burning" is that takes place in the ordinary fireplace.

If you want to make a fire you of course have

to have a fuel. But equally important is the presence of enough air. If your clothes by any accident catch fire, you are warned to throw a wrap tightly around you, so as to prevent access of air. Without air there can be no burning, no matter how much coal or wood there may be.

Oxygen. But what is there in the air that is so essential to burning? The chemist tells us that it is the oxygen. This gas is present in the air to the extent of about twenty per cent. If a sample of air be taken and the oxygen removed from it, your paper will not burn; nor will anything else that ordinarily burns in the air. If, on the other hand, you take your burning paper or lighted candle, and thrust it into a jar containing the removed oxygen, the paper or candle will burn with a brilliancy that dazzles the eye.

Priestley, an Englishman, who later took refuge in Pennsylvania to escape from religious persecution, first isolated this wonderful oxygen in 1771, but it remained for Lavoisier, a Frenchman, to show just in what way this gas is related to the process of burning, and to the process of respiration or "burning in the body." He did this work while the French Revolution was doing *its* work; and he was rewarded for his labors by being guillotined.

Lavoisier. Lavoisier showed that if you take a piece of coal and burn it, the carbon and the hydrogen, the two chief elements in the coal, combine with oxygen, forming carbon dioxide and water respectively; thus

carbon plus oxygen yields carbon dioxide;
and hydrogen plus oxygen yields hydrogen oxide (commonly known as water);

and that as a result of this combination, a large amount of heat is evolved.

Lavoisier next showed that much the same thing takes place when food is taken into the body. Here also the carbon and hydrogen in food—just as certainly present in meat and bread as in wood and coal—combine with the oxygen in the air obtained by breathing, to yield carbon dioxide and water, at the same time liberating heat.

That we actually liberate carbon dioxide and water can be easily shown. Take a straw used for drinking a soda and blow through it into a glass containing lime water; the lime water will immediately turn milky. The same is true if you thrust a lighted candle into a jar, keep it there for a few seconds, then take it out and add a little lime water to the jar and shake. In either case the chemist can prove to you that it is the carbon dioxide released from your body or from the lighted candle that turns the lime water milky.

Likewise if you blow on a cold surface, say your glasses, the surface becomes moist. If you burn your candle surrounded by a tall glass chimney, you will notice that the upper portion of the chimney becomes moist; this moisture, to be sure, soon disappears, but that is due to the heat from the candle.

Just as heat is produced when the carbon and hydrogen from the candle or coal unite with the

oxygen to form carbon dioxide and water, so heat is produced when these elements in the food we eat unite with the oxygen in the air we breathe to produce the same products.

Now we know why the doctor's thermometer thrust in your mouth registers a higher temperature than the same thermometer hung in the room. And just as the coal gives the heat and therefore the energy necessary to convert the water in the boiler into steam and so run the engine, so probably the food we take into our system gives us the energy needed to carry on our daily work.

Measuring Heat. Obviously enough, the value of the fuel must depend primarily upon the amount of heat you can get out of it. If one ton of coal mined in Pennsylvania gives you one and one-half times as much heat as a ton of coal mined in Wales,—if there are more carbon and hydrogen and less impurities in one sample than in another—then you will turn to Pennsylvania for your coal supply; provided, of course, the Welsh coal is not so much cheaper as to offset the increased fuel value of the Pennsylvania coal.

The question, then, of how much heat you can get out of a ton of coal—or, as the coal merchants and chemists put it, what is the fuel value of one ton of coal—becomes of paramount importance.

And if the value of the coal lies in the amount of heat you can get out of it, may not the value of food depend upon the amount of heat *it* produces when "oxidized" in the body? Hence the importance attached to a means for measuring heat.

CHAPTER II

CALORIES

I can buy five pounds of tea from my grocer or a quart of milk from the dairy; but suppose I go to my coal dealer and ask him for one ton of heat? He would probably look me over, then look at his neighbor and point to his forehead. The coal dealer can give me one ton of coal which when burnt gives heat, but neither he nor any other man can sell me one ton of heat as a market commodity.

Why not? Simply because you cannot isolate the heat and keep it. The water may be hot; the iron may be hot; many things may be; but the heat in all cases is associated with something you can see or touch. You cannot see heat and you cannot touch it. If water is hot, what you see is the water and what you touch is water. If boiling water burns your fingers whereas cold water does not, our scientist friends inform us that in reality the difference between the two states is that in the hot water, the molecules are in more rapid motion than in the cold water. The molecules are in more rapid motion. They run faster. They seem to have more *energy.*

Heat indeed is now known to be a *form of energy,* just as light and electricity are forms of energy. But if so, how are we going to measure this heat? What standard of reference can we adopt by means of which this heat can be measured? In English-speaking countries the yard and the pound are used as standards for measure and weight respectively. What standard of reference can we apply to that which we cannot weigh and cannot measure?

Water is the best-known and the most useful liquid. Suppose we take some water and heat it, and while heating it let us thrust a thermometer into the water. The mercury column of the thermometer will rise, and whenever this mercury rises we say the temperature is increasing. There seems to be a very simple relationship between the amount of heat the water acquires and the rise of mercury in the thermometer. Why should it not then be possible to measure heat in terms of the rise of the mercury column?

Calorie. That is exactly what is done. We take as a standard of reference *that amount of heat which is required to raise one kilogram of water one degree centigrade,* and we call this the *calorie.* (The kilogram is approximately equal to about two and one-quarter pounds. The kilogram, based on the metric system, is a standard of weight invariably used in scientific work and very extensively used on the continent of Europe. Since the centigrade scale of measuring temperature is based on the metric system, it is used in scientific

work. One hundred degrees on the centigrade scale are the equivalent of 180 degrees on the Fahrenheit scale. The doctor's thermometer reads degrees Fahrenheit. When he says that your temperature is normal, and that it therefore is around 98, he means 98 degrees Fahrenheit. On the centigrade scale this temperature would correspond to about 37.)

Calorimeter. Now suppose we take a piece of coal, crush it and weigh one gram of it (which represents the one-thousandth part of a kilogram), and then put this one gram of coal into a vessel surrounded by another vessel containing one kilogram of water, into which a thermometer is inserted. Let us further suppose that when we burn this coal none of the heat evolved can escape except by way of the water. The heat the coal evolves in burning will therefore be transmitted to the water, and this transmission of heat will be registered by the thermometer in the water. This thermometer, let us say, will register an increase of seven degrees. The amount of heat evolved by one gram of coal when burnt will therefore be the equivalent of that produced when one kilogram of water is heated seven degrees; or it is the equivalent of seven calories. For remember that one calorie represents that amount of heat necessary to raise one kilogram of water one degree, and two calories would represent that amount of heat necessary to raise one kilogram of water two degrees; and so on. On the other hand, instead of having the weight fixed and the tempera-

ture changing, we can reverse the order and have the temperature fixed and the weight changing. For example, one kilogram of water raised seven degrees is the equivalent of seven kilograms of water raised one degree; both are equivalent to seven calories.

The calorie is the unit of heat. An arrangement for measuring heat is known as a calorimeter.*

Food Values in Terms of Calories. We have seen how Lavoisier had shown that food in the body undergoes much the same change that coal does when it is burnt; in both cases there is a union with oxygen, with the ultimate production of carbon dioxide and water, and the liberation of heat. The heat formed in the body as a result of the "oxidation" of foods, supplies our energy requirements.** If this energy is so intimately related to heat production, and if heat is measured in calories, why cannot we measure foods in terms of energy-content, by measuring the number of calo-

* The calorie discussed above represents the large calorie. The small calorie is that amount of heat required to raise one *gram* of water one degree; it is therefore the one-thousandth part of a large calorie.

In actual practice the calorimeter consists of a steel bomb, often lined with copper and gold-plated, and a tightly fitting cover with screw collar attachment. A weighed sample to be tested is placed in a capsule within the bomb. The latter is now charged with oxygen under pressure, closed, and immersed in a weighed amount of water. The sample is ignited by means of an electric fuse. The water is constantly stirred and the temperature taken at short intervals by means of a carefully calibrated thermometer, usually reading to one-thousandth of one degree.

** Of course, food has other important functions, not the least of which is to build up or replace cellular tissue, but for our immediate purposes in this chapter these need not be considered.

ries that a given quantity of food will yield when burnt? A perfectly natural question.

Just as we can burn coal and determine the calories liberated, so by suitable means, we can burn any one of the many varieties of food and estimate the calories it produces. In this way we arrive at the conclusion that one food is richer than another because it liberates more calories when burnt; because, in other words, it yields more energy.

To illustrate with an example: The heat value in calories of one pound of corned beef is about 1200; that of one pound of tomatoes, 100. According to our experiment one pound of beef yields twelve times as much energy as one pound of tomatoes; or, one pound of beef yields as much energy as twelve pounds of tomatoes.

The Body Furnace. But now the reader may ask another question: If, as you say, the body in many ways behaves like a furnace, with food serving as fuel, from which heat is produced, why cannot we find out the amount of food or fuel the body uses by measuring the amount of heat it evolves? Why not do to man what we did to a piece of coal or to a portion of food?

But you will at once raise the objection that such an experiment would involve the sacrifice of a human being, for you would have to "burn" him up; a phase of the experiment which would concern the subject of it even more than the experimenter. On second reflection, however, you

will notice that your objection does not really hold. For in man—in all "things that have the breath of life"—the "furnace" is inside of him. In reality, there are millions and millions of these "furnaces" represented by the millions and millions of cells. The food after careful preparation by the digestive system reaches these cells, is there joined by oxygen from the lungs, and then "oxidized." No light need be applied either to the cells themselves or to the body as a whole.

Just how the cells do their "oxidation" work is a mystery which has not yet been solved, though physiologists have a workable hypothesis to explain it. What the cells do we have not been able to repeat in a test tube; which is another way of saying that the mystery of man is man.

Let us return. We take our man and put him into a chamber so constructed as to enable us to measure the heat he produces in the course of a day.* We do not have to do to man what we did to coal—apply a light; his cells have their own way of "burning" material without any help from us. We find that this man weighing 160 pounds evolves 2200 calories in twenty-four hours. He receives "square meals" during the day. What deduction may we draw from such an experiment? Obviously enough that the man must have "burnt up" food to the extent of 2200 calories, and that therefore food yielding 2200 calories must be supplied to him every day so that he may have the

* Those interested in the actual details may consult Sherman: *Chemistry of Food and Nutrition*, p. 158 (Macmillan Co., 1918).

necessary energy; so that he may continue to *live.*

By repeating such an experiment with hundreds of different men, of all sizes and all ages, we can arrive at an "average" figure.

Man's Energy Requirements. As a matter of fact, basing such experiments on the weight of the average man—about 160 pounds—the energy requirements do amount to about 2200 calories, *provided he is resting.*

There must be great variations in the energy, and therefore food requirements. A man who is sick does not eat as much as a man who is well. A lumberman needs more calories than a clerk; an adult more than a child; a man usually more than a woman.

Let us take some concrete cases. Take the average man while sleeping. Sleeping does not suspend cellular activity. Oxidation of foodstuffs goes on, but not to the same extent as during the day, when the man is active. During every hour's sleep he expends about 65 calories. If he were to sleep twenty-four hours he would expend 1680 calories, but since he is a normal man and sleeps no more than about eight hours, he expends about 520 calories during this period. Let us take it that going and coming from work consumes two hours of the day. Walking is a light form of exercise requiring 170 calories per hour; two hours give us 340 calories. If the man is engaged in manual labor, as a carpenter perhaps, and works the "union" time of eight hours, he will need 240 calories per hour while so engaged; a total for the

eight hours of 1920 calories. Our carpenter has six hours left for recreation—for reading newspapers and gossiping and seeing a "movie." We must count the recreation at a hundred calories per hour; a total then for six hours of 600 calories. Adding up our calories for the twenty-four-hour period, we get $520 + 340 + 1920 + 600 = 3380$ as the total requirement per working day. You see, this is considerably above the 2200 calories that the average man needs when resting.

You may, with Tigerstedt, classify the requirements by the trade pursued. A shoemaker, he tells us, should thank the Lord when he gets the equivalent of 2400 calories, a weaver 2700, a farm laborer 4100, a lumberman over 5000.

Woman's Energy Requirements. Women need less. A seamstress rests satisfied—or should rest satisfied—with 1800 calories; a bookbinder with 2000; a servant with 2800; a washerwoman with 3200. Remember here that the average weight of woman is less than that of man; so that in proportion to the weight, the woman may receive just as many calories as man.*

Children. Children when one year old may need about 1100 calories. The increased requirements for each succeeding year are—*very roughly*—about 100 calories. Here again we encounter marked differences between the requirements of boys and those of girls. Where a girl of ten ex-

* The phrase "getting so many calories" cannot, of course, be taken literally. From all that has been said in this chapter, we translate this oft-used expression to mean that amount of food which, when oxidized in the body, yields "so many calories."

pends 1800 calories, a boy of that age may expend 2300.

An Army's Food Requirements. The food requirements of an army have always been the subject of extremely careful investigation. The following figures compiled during the late war are of interest for two reasons: they show the comparatively high calorific requirement of the American soldier (somewhat related to the state of prosperity of the country in which he lives), and the decidedly different requirement of the soldier when in camp and in the field.

	Training	Field
American Soldier	3900 calories	4800 calories
British "	3400 "	4600 "
French "	3300 "	3600 "
Italian "	2500 "	3300 "

Starvation. If a body expends energy, that energy must have a source. The law of conservation of energy teaches us that nothing is created and nothing destroyed, *but things do change.* So if the body needs 3000 calories, these have their source in the food taken. But where does the hungry man—the starving man—get his energy from? The answer to that is that no matter how reckless a man may be in his spending habits, the body is never quite so reckless; it always stores up a little food for "the rainy day." But this little capital does not last for many days. When the stored food has disappeared, the energy requirements continue to be met by the "oxidation" of the tissues—the muscle, the fat, the skin, the liver,

the blood are used up bit by bit until the human machine snaps. Most remarkable is the fact that to the very last the brain and heart continue to function with presumably little impairment. They are the last to be attacked.

The question is often asked, to what extent does mental work influence calorific needs? No very decided answer to this all-absorbing question can be given. Many experiments have been tried, but the results have been uniformly negative. In one of these experiments Dr. Benedict, of the Carnegie Institute, measured the heat evolved by a number of college students during examination periods. These poor fellows were penned up in calorimeters and their examination questions then set before them. They "sweated blood." When the exams. were over, the same men were put in calorimeters and allowed to rest for a period equivalent to their examination period—three hours—and during this time the heat was measured. No material difference between the two measurements was noticed.

However, it may be noticed in passing that Tashiro, a talented Japanese instructor at the University of Cincinnati, has shown that when a nerve fiber is stimulated, the carbon dioxide output is increased; which is another way of saying that when the nerves are active, "oxidation" is increased, and therefore the calorific needs are greater. Tashiro had devised an apparatus for detecting the minutest traces of carbon dioxide, and it was only with so delicate an instrument that the increased output of carbon dioxide could be

determined. The amount measured was so small, that it can hardly make any appreciable difference in ordinary metabolic studies. The calorie is a true guide to muscular activity; it seems to be no guide to the activity of the brain.

CHAPTER III

CARBOHYDRATES, FATS AND PROTEINS

We have reached the conclusion that one method of estimating the needs of the body is to ascertain how much heat the body liberates. If we assume that for the average, active individual the heat liberated in 24 hours corresponds to 3000 calories, then it becomes perfectly evident that in order to retain our health, we must consume a quantity of food which, when burnt in the body, will give such 3000 calories. From tables that can be found in any book on dietetics (see Appendix) we can find how many calories a pound any of the common foodstuffs will yield when consumed. It becomes then merely a matter of selecting enough food to give the necessary 3000 calories.

The Calorie Is Not the Only Factor Involved. Unfortunately for the simplicity of the science of dietetics, the question of adequate nutrition is a far more complicated one. Calories alone do not completely solve the problem. For take an example borrowed from our previous chapter. We there stated that one pound of tomatoes represents a fuel value of 100 calories. If your requirements are 3000 calories a day, suppose I were to suggest

to you that you satisfy these requirements by eating 30 pounds of tomatoes? You would laugh at me. You would say you could not do it; it would make you sick. And so it would, despite all assertions that your fuel requirements would be satisfied. You do not object to tomatoes, provided that meat and bread and butter and milk take the place of most of the 30 pounds of tomatoes. Quantity alone is not at all sufficient; quality and variety are equally important. And this brings us to the next step in our subject.

Carbohydrates, Fats and Proteins. When the chemist examines the foodstuffs common to man, he finds that he can classify them under three broad divisions: carbohydrates, fats and proteins. There are plenty of differences among the individual foods in each group, but they show enough common characteristics for them to belong to one family and to be differentiated from foods belonging to either of the other families. The fate of different carbohydrates given to the body is much the same. This is true of the fats and proteins. It is much like classifying the people of the world into the white, yellow and black races. The 80 or 90 million white people in America show plenty of differences among themselves; but their color and other anthropological features divide them very sharply from the yellow and black people.

We can best form an idea of these three classes of foodstuffs by naming foods rich in one of the three. Starch and sugar are excellent examples of carbohydrates. Starch is found in abundance

in flour and all cereals, in rice and potatoes. Besides the sugar cane and sugar beet, sugar (of several varieties) is found in milk and fruits. Butter and the "fat" of meat, and much of cheese and all oils represent the class of fats. Much of the egg and meat and cheese and some of the milk contain proteins. Very few of the common foods contain one hundred per cent of any one of the three classes of foodstuffs; usually each foodstuff consists of various mixtures of two or three of them, as the following table, representing the composition of some common foods, will make clear. (Approximate figures are given. The difference between 100 and the sum of the first three figures in a horizontal column represents—roughly—the % of water. Mineral salts, though pres-

Food	Protein (Per cent)	Fat (Per cent)	Carbohydrate (Per cent)	Fuel value, per lb. (in calories)
Bread (average "white")	9	1	54	1200
Potatoes	2	0.1	18	380
Milk (whole)	4	4	5	320
Butter	1	85	..	3500
Cheese (American pale)	29	36	0.3	2000
Oranges	0.8	0.2	12	230
Apples	1	0.5	3.9	100
Sugar (cane)	..	..	100	1800
Eggs	13	10	..	670
Beef (fore, shank, lean)	22	6	..	647
Beef (ribs, fat)	15	36	..	1700
Mutton (leg)	20	12	..	860
Veal (breast)	20	11	..	817
Fish (mackerel)	19	7	..	630
Fish (salmon)	14	8	..	580
Peanuts	25	38	24	2500
Peas (canned)	4	0.2	10	252

ent, and though enormously important, are not included because they will be discussed separately in the next chapter. See particularly page 37 and following.)

This table is instructive. You will notice—what has already been intimated—how all of the common foods are mixtures of two or three of the foodstuffs. Cane sugar and butter are notable exceptions. You will notice, furthermore, how relatively rich in carbohydrates are bread and potatoes, and how relatively poor in carbohydrates but rich in protein and fat are cheese and eggs and meat and fish. You will notice, if you glance once again at the table, that in the case of milk, though the percentages of fats, carbohydrates and protein are rather small, there is a fairly equal distribution of these three.

Now why should milk, the sole food of infants, contain substantial quantities of all three foodstuffs? Why from time immemorial have men selected their food in such a way as to include substantial amounts of the three? There must be some good reason for it. There must be some reason why milk does not contain one hundred percent of carbohydrate alone, and why the adult's food does not consist of one hundred percent fat or protein alone.

The Function of the Three Classes of Foodstuffs. As a matter of fact, each class of foodstuff has a very well-defined function. The carbohydrates are primarily energy-formers. Our muscular energy is mainly derived from the carbohydrates we eat.

It is in the course of such muscular activity that heat is produced.

These carbohydrates, and to a certain extent the fats, have still another important function. We say they "protect" the proteins. This "protection" consists in allowing the protein to attend to its particular business of tissue up-building and repair, without having to engage to any large extent in the side line of supplying energy. Within certain limits, the protein can take the place of carbohydrate as a source of energy, but the carbohydrate *cannot* take the place of protein in building up tissue. We wish then to hamper as little as possible a task which the protein alone can do.

Some physiologists are now of the opinion that the proteins' all-important function of tissue upbuilding is only possible in the presence of carbohydrate, and the constant production of sugar (a typical carbohydrate) in diabetes, even though no sugar is supplied to the body, is pointed to in support of the theory. This suggests another extremely important function of carbohydrates.

What has been said of carbohydrates is very largely true of fats, with this difference: that on the whole the carbohydrates are more readily "oxidized" in the body; and—and this is the important point—the fats act as a *reserve supply* for the fuel needs of the body. The humps of camels and the fattening of hibernating animals before winter illustrate this property of fats. Your fat is not used until your carbohydrate supply becomes ex-

hausted; and if you eat more carbohydrate than the immediate needs of the body require, a considerable portion of the excess will be converted into fat and stored as such. That explains why fat people avoid not only foods rich in fat but also those rich in carbohydrates.

The proteins are by far the most important of the three classes of foods, and reasons have already been given for this view. Let us give still another. When we analyze living matter—which, unfortunately, can be done only after all life has left the living matter—we find that the elements always present are carbon, oxygen, hydrogen and nitrogen. There are also other elements in much smaller proportions, but they need not concern us just yet. When we analyze the food we eat we find that the carbohydrates and fats consist of carbon, hydrogen and oxygen only. To be sure, the proportions of carbon, hydrogen and oxygen vary with the different fats and carbohydrates; but in so far as the elements out of which the fats and carbohydrates are formed are concerned, they are always found to be carbon, hydrogen and oxygen. It is only when we analyze proteins that we discover the other element so essential to life, nitrogen. Hence the indispensability of proteins.

You might say, but is not there plenty of free nitrogen in the air, and do we not therefore absorb nitrogen every time we breathe? We do take in nitrogen every time we breathe, but we do not assimilate it; we cannot assimilate nitrogen in the *uncombined* state. If you analyze a sample of air

before you inhale it and then analyze it after you have exhaled it, you will find that the percentage of nitrogen remains the same; only the percentage of oxygen has changed.

Now just as the soil's need for nitrogen cannot be obtained from the nitrogen of the air, but from one of its compounds, such as Chili saltpeter, so the body's need for nitrogen is likewise unobtainable from free nitrogen, but must be supplied by some nitrogen compound, preferably protein.

The carbohydrates and fats are the main source of energy of the body. The carbon, hydrogen and oxygen in these substances are changed to carbon dioxide and water, which in their turn consist of carbon, hydrogen and oxygen; for remember in all chemical changes—in *all* changes—we never create and never destroy, but merely *change*. If we take sugar into our system (and what is true of sugar is true of fats and carbohydrates in general) the ultimate change that it undergoes may be represented by this equation:

$$\underset{\text{(sugar)}}{C_{12}H_{22}O_{11}} + \underset{\text{(oxygen)}}{12\,O_2} \rightarrow \underset{\text{(carb. diox.)}}{12\,CO_2} + \underset{\text{(water)}}{11\,H_2O}$$

(C, carbon; H, hydrogen; O, oxygen)

Without attempting to go into the chemistry of such a reaction, without in fact requiring any knowledge of chemistry, you can easily see for yourself that not only are the same elements present on both sides of the equation, but the same amounts

of these elements. They are in different combinations, however.

But this equation, like every other chemical equation, fails to show everything about such a reaction. For example, it fails to tell us that a very considerable amount of heat, measured in calories, is evolved when the sugar and the oxygen combine; and this heat is the all-important factor in so far as the body is concerned.

But the equation fails to answer another question, of particular consequence just now to the student and philosopher. Extensive researches have shown that fats and carbohydrates are not *immediately* broken down into carbon dioxide and water; there are a number of intermediate stages. One or two of these intermediate steps have been located, but much of what goes on in the body factory still remains a mystery.

Since the proteins also contain carbon, hydrogen and oxygen, besides nitrogen, the first three elements in the protein molecule can be oxidized to carbon dioxide and water in much the same way as the fats and carbohydrates, with the consequent liberation of energy in the form of heat. But proteins, as we have already discussed, serve another purpose; and besides, they are more expensive foods than the fats and carbohydrates. And even if, theoretically, there is no reason why a person cannot live on protein alone, provided he takes enough of it, and does not mind the extra expense, experience teaches us that to live on protein alone

is not advisable. The tax on the body in having to handle such large quantities of protein is such that, in time, the vitality of the organism is appreciably diminished.

Minimum Food Requirements. From what has been said regarding the three classes of foodstuffs, it becomes evident that calories do not represent the sum total of nutritional requirements. Besides a sufficient number of calories, we must have a judicious distribution of these calories in terms of the three classes of foodstuffs. But how much of each must we take? Are there any *minimum* requirements of protein, fat and carbohydrate?

Taking up the fat and carbohydrate first, as the easier problem to solve, we may state that since both of these serve primarily as sources of energy, the amounts taken per day should be such as to correspond to the energy requirements of the body. If the average man liberates heat in the neighborhood of 3000 to 3500 calories per day, he should be given enough fat and carbohydrate to form this amount of heat. Of course, the fact should not be lost sight of that the very constitution of the protein molecule shows it to be an energy-forming as well as a tissue-replacing substance. That means that the amount of fat and carbohydrate eaten need constitute a little less than the equivalent of 3000 to 3500 calories. That means that in order that we may know how much less than 3000 to 3500 calories the fat and carbohydrate need produce, we must first ascertain the minimum protein requirements of the body.

Instinct as a Guide to Man's Food Requirements. As with all questions relating to food, the earlier experimenters on protein requirement were largely guided by mankind's accumulated experience in the matter. When the average of many thousands of examples was taken, the amount of protein consumed per day by the individual was a little more than 100 grams. If we take the rough estimate of 30 grams as being the equivalent of one ounce, the hundred grams would be the equivalent of a little more than three ounces.

Around this protein requirement of 100 grams per day there have raged battles royal, and the decisive test has yet to be made. From the purely economic standpoint this protein requirement becomes an extremely important one, because the proteins are the most expensive of the three classes of foodstuffs. If then we could, without harm to the population, replace part of the protein by the other two foodstuffs, it would be conferring a benefit on the poor part of the population, unless by so doing, our good-natured speculators would come to the rescue of their pockets and demand an increase in price for fats and carbohydrates!

Some information was shed on the subject of protein requirement by a careful examination of the diet of Asiatics, particularly the Bengalis in India. Their diet is largely vegetarian, and they consume not more than 37 grams of protein per day—about a third of what the European consumes. The Bengalis, it was pointed out, are an inferior race to the Europeans, both physically and mentally,

and this inferiority was now largely attributed to deficient protein consumption.

This conclusion did not go unchallenged. Scientists attempted many quantitative experiments to arrive at some definite results. Unfortunately for the scientist, the human body, though a mechanism in some ways, is still far more than a mechanism. What holds true of chemical reactions does not necessarily hold true of body changes. Here there are so many factors over which man has as yet no control; and even when he realizes some of these factors, they are rarely so well-defined as to stand the test of experiment.

Mr. Horace Fletcher. But if scientists performed quantitative experiments, there were others, not scientists, who performed what some like to call "common-sense" experiments. A particularly conspicuous individual in this direction was Mr. Horace Fletcher, whom readers of newspapers must remember. Here was a man who had passed middle age and who had been refused life insurance because of delicate health. "Fie upon ye!" cried Fletcher; "there is absolutely nothing the matter with me, except that I eat much too much, and am not careful in what I choose." Whereupon Mr. Fletcher began by cutting down calories and increasing the time taken to masticate food. "Fletcherism" became a fad.

From our standpoint what is particularly noteworthy in Mr. Fletcher's praiseworthy experiments on himself is the relatively small quantity of protein he consumed. Mr. Fletcher's physique im-

proved decidedly. Fatigue and lameness and colds all disappeared. Naturally enough, Fletcher attributed his success to the adoption of his modified regimen; and in this modified diet, a conspicuous feature was the small amount of protein it contained.

Nitrogen Equilibrium. There is another way of attacking the problem of protein requirement—a more scientific way. But before we describe this, a few preliminary observations become necessary.

The reader will remember what we said above concerning the three classes of foodstuffs,—that only the proteins contain the element nitrogen. When we come to trace the course of this protein in the body we find that, in so far as the nitrogen part of the protein is concerned, it is mainly occupied in replacing decayed tissue. Whenever the cell takes up the nitrogen compound to build up tissue, it gives up a corresponding amount of a nitrogen compound which represents the waste material. This waste material finds its way chiefly into the urine. Very small quantities are found in the feces and sweat.

Now suppose we determine the amount of nitrogen in the food we eat, and then determine the amount of nitrogen excreted. If the quantities are approximately equal we say we have reached a "nitrogen equilibrium": the expenditure is equal to the income.

All *normal, adult* people show such a "nitrogen equilibrium." The case is different with growing children. The child grows; the number of his

cells multiply; he must therefore keep some of his nitrogen for additions to his little house. Here the nitrogen intake will be greater than the output.

Sick men and sick children may serve as the reverse example of the healthy, growing child. Here the tissues may go to waste without any corresponding replacement. That would mean that the nitrogen eliminated from the body is more than the amount the body receives from its food.

Where man has reached the limit of growth and is in a healthy condition, the output and income of nitrogen equal one another. If you give him twice as much protein (and therefore twice as much nitrogen) one week as another, you will soon find that this healthy man will begin to eliminate twice as much nitrogen as he did formerly. The body, you see, does not *store* protein the way it stores fat. Eat more fat than you can handle, and the extra fat accumulates in your adipose tissue and you become a fat man. (Sometimes you become a fat man without eating too much; but such cases belong to pathology.) Eat more carbohydrate than the body can handle, and the surplus stock is converted into fat and stored as before. Eat more protein than the body can utilize and the surplus is thrown out. As has already been said, the last statement does not hold true for children.

On the face of it you would say that if your adult shows that his nitrogen output and income balance one another—that he is in "nitrogen equilibrium"; that then he gets all the nitrogen neces-

sary to rebuild waste tissue. He gets what he needs and in sufficient quantity.

Now the nitrogen comes from the protein, and the protein alone. Experience has shown that this nitrogen constitutes about 16 per cent of the total protein. This means that we need merely multiply the amount of nitrogen found by the number 6.25 to give us the amount of protein eaten; for 16 times 6.25 equals 100.*

Suppose an extended series of trials on a man show us that when he eats food containing the equivalent of 16 grams of nitrogen per day he also eliminates the equivalent of 16 grams of nitrogen. His balance sheet is clear. He is probably a healthy, normal individual. He is supplied with food in sufficient quantity. These 16 grams of nitrogen in the food show that he must have eaten 16 times 6.25, or 100 grams of protein. So we may arrive at the conclusion that 100 grams of protein are probably necessary for our individual to retain his good health. This will give an idea of how we arrive at a minimum protein requirement.

Now let us take one or two examples to illustrate this method of investigation.

Professor Chittenden's Experiment. Yale men will remember Chittenden, the director of the "Shef." Scientific School. Some years ago Chittenden selected a number of instructors, including

* The food may also include nitrogen compounds other than protein, but it is unnecessary at this stage to complicate the situation more.

himself, students and army men attached to the hospital corps, and made them the subjects of an experiment in which the amount of protein in the diet was gradually reduced from a little over 100 grams to 50, and in some cases to 30 grams per day. The loss in energy due to reduction in the protein supply was counterbalanced by increasing the quantity of fat and carbohydrate, so that the total number of calories remained constant. Even with as low as 30 grams of protein (about one ounce) the "nitrogen equilibrium" was maintained, showing apparently that the health of the subjects was in no way impaired. Chittenden of course drew the obvious conclusion that our protein consumption could be cut to one-half without in any way lowering the vitality of the individual. He maintained—and here he agreed with Fletcher—that some of the ills of humanity were due to excessive protein intake; and that therefore the reduction of the protein in the food eaten also lessened the possibilities of disease.*

Dr. Hindhede. Chittenden's views were supported by Dr. Hindhede, of the Nutrition Laboratory in Copenhagen; and during the strenuous days of the late war, when the food of people even in the neutral countries was limited, Hindhede's influence was such that the feeding of the Danish population was left very much in his charge.

Objections to a Too Low Protein Diet. From

* For further details the reader may consult Dr. Chittenden's very readable works: *Physiological Economy in Nutrition* and *The Nutrition of Man*. Both are published by Frederick A. Stokes Co.

what has been said, I do not want the reader to get the impression that the problem of protein requirement has been definitely solved in favor of the rather low figures of Chittenden and Hindhede. As a matter of fact, the tendency among the most prominent food experts is to retain a figure nearer to 100 grams of protein than 50, as the rations of armies and civilian populations, guided by the advice of such experts, shows (see below). There are one or two important reasons for preferring the older figures. One is that scientific experiments are usually of short duration—a few weeks, sometimes a few months;* and a diet that may do little harm in the course of a month may do infinite harm if extended over a period of years. This objection can be made to Professor Chittenden's work, and is, in fact, so general that it can be raised against many of the experiments in nutrition, unless animals, such as rats, are employed whose duration of life is considerably shorter than man's; so that months in the life of a rat may correspond to years—and even more—in the life of a human being. But here again you may say that what is true of the rat need not necessarily be true of man. Your point is well taken.

The gratifying results obtained in Denmark during the war by feeding the people little protein diet, as suggested by Dr. Hindhede, look like a victory for those who urge a low protein diet. Unquestionably most of us do eat more protein than

* Some of Dr. Hindhede's experiments are exceptions, for they lasted from one to two years.

is necessary; but the question arises, as we read Dr. Hindhede's paper, whether the decreased mortality in Denmark was not to some extent at least due to a decreased alcohol consumption?

But there is still another objection against adopting a too low protein standard. The discussion in a subsequent chapter will show that what holds true of calories holds true of protein: that just as you may supply the body with all the calories it needs and yet ruin the system if a well-balanced selection of the three classes of foodstuffs is not chosen, so you may fulfil protein requirements and still ruin the body, because the type of protein you have selected is poor in certain very necessary constituents. As the difference between different proteins is largely a matter of the *amount* of these necessary constituents, it becomes self-evident that 100 grams of protein are more likely to give the necessary amount than 50.

You may say, well then if that is the case, why not increase the protein intake even further? Why stop at 100 grams? Why not go on to 200 and 300 grams? The objection to too large quantities is one mainly of cost. Further, an excess of protein means an excess production of waste products. The drain on the system becomes too great, and the possibilities of a resulting lowered vitality are very much increased.

You have then to find the happy medium of satisfying the protein requirements and yet of not more than satisfying such requirements.

If I have gone into the subject of protein require-

ment at some length, it is because so much of the entire subject of dietetics depends upon it; so much of the health of populations depends upon it. And yet we are still at some distance from a complete solution of the problem.

A Satisfactory Diet. Taking into consideration all that has been said, and some other factors that cannot well be discussed in a volume of this kind, experts have adopted the following as a satisfactory diet for a healthy man of average weight: protein 100 grams (3.6 ounces), fat 100 grams and carbohydrate 500 grams (18 ounces). The variations for different individuals are quite considerable, but the example just given may serve as a basis.

Experiments have shown that one gram of protein when "oxidized" in the body yields heat to the extent of 4 calories; that one gram of fat under identical conditions will yield 9 calories; and one gram of carbohydrate 4 calories. From 100 grams of protein, therefore, we get the equivalent of 100 times 4, or 400 calories; from 100 grams of fat we get 100 times 9, or 900 calories; 500 grams of carbohydrate give us 500 times 4, or 2000 calories. The total energy value then is 400 plus 900 plus 2000, or 3300 calories.

Professor Bayliss gives us the following figures: 100 grams of protein are contained in 18½ ounces of steak, 5 pints of milk, 1½ pounds of oatmeal, 13½ ounces of dried meat, or 2½ pounds of bread; 100 grams of fat are contained in 4½ ounces of butter; 500 grams of carbohydrate are contained in

2 pounds of bread, ¾ pound of oatmeal, 7½ pounds of potatoes and one pound of sugar. (See the table in the Appendix. Those of my readers who are interested in the composition of foods and their calorific value may write to the Superintendent of Documents, Washington, D. C., requesting Bulletin 28, Office of Experiment Stations, U. S. Department of Agriculture. Enclose 10c. but not in stamps.)

Soldiers' Rations. Food experts attached to the armies in the late war had excellent opportunities for studying the nutritional needs of large bodies of men. The war ration adopted by the British for their men in the field was protein 158 grams, fat 200 grams, and carbohydrate 514 grams; a total of 4600 calories. This, you see, is far above that necessary for the average man in peace time, and even above what is necessary for the soldier when in training camp. Our own soldiers when in training received protein 139 grams, fat 129 grams and carbohydrate 539 grams; a total of 3980 calories.

The following "garrison ration" was the basis for feeding our soldiers in the training camps (the numbers refer to ounces): meat 20, beans 2.4, prunes 1.28, sugar 3.2, lard 0.64, syrup 9.32, flour 18, potatoes 20, coffee 1.12, milk 0.5 and butter 0.5. Also small quantities of salt, pepper, cinnamon, vinegar and flavoring extract. "For calculation of the value of the ration," writes Major John R. Murlin, in charge of the food supplies at the training camps, "certain definite substitutions are made.

For example, 70 per cent of the meat component is issued as fresh beef, 20 per cent as ham, and 10 per cent as bacon; 50 per cent of the bean component is calculated as beans and 50 per cent as rice; 70 per cent of the potato component as potatoes, 20 per cent as onions and 10 per cent as tomatoes, etc. . . . The average value of the ration in the training camp . . . has been in the neighborhood of 39 cents per man per day"—a rather modest sum when compared with the cost of the ration of the average citizen!

CHAPTER IV

MINERAL MATTER

When you burn a piece of coal or paper or wood you always have some ash left. The housewife and the stoker consider the ash nothing but a nuisance. It cannot be burnt and therefore is of no heat value. A relatively large percentage of ash in your coal immediately decreases the value of the fuel.

If you burn a piece of meat or any of the common foods, you will also get some ash left. In order to see this ash it will be necessary for you to do a little more burning than the careless housewife does when she manages to spoil her dinner. The chemist burns such food by placing it in a porcelain receptacle which he calls a crucible, and putting the latter in turn in a muffle which can be heated red hot. In time the charry product gives place to a gray and sometimes almost pure white mass, the color depending upon the variety and quantity of the various mineral constituents in the ash. The operation is now complete. All the black carbon has disappeared. What is left is the "ash." It is material in which the elements sodium and potassium and calcium and phosphorus predominate. The ash is called "inorganic" because

it is free from carbon. A substance containing carbon—like the meat we started with—would be called "organic."

Mineral Matter or "Ash" an Essential Part of the Diet. Useless as this ash is to the housewife and stoker, the ash in our food is an indispensable part of the dietary. We could as easily dispense with the protein as we could with the ash, or, as it is sometimes called, the "mineral matter"; and this is merely another way of saying that the absence from the diet of either one of these would soon cause death.

Not only then must our calorific requirements be fulfilled; not only must there be a careful distribution of our food in the shape of protein, fat and carbohydrate; but the food must also contain a certain amount of ash or mineral matter. Fortunately, all of our foods contain mineral matter to a greater or less degree; so that without necessitating any particular selection on our part, we usually satisfy the mineral requirement without much difficulty.

The Elements in Mineral Matter. When we submit a bundle of cells, consisting of living matter, to chemical analysis, we find that fats, proteins and carbohydrates are present in much the same way as in our foods. The general composition of living matter and of the food we eat is much the same. Another type of chemical examination shows us that living matter consists of such elements as carbon, hydrogen, oxygen and nitrogen, again in much the same way as our foods do. In

addition, there are smaller quantities of calcium, phosphorus, potassium, sulphur, sodium, chlorine, iron, iodine, etc. Understand that these elements are not present in the free state. You cannot take a piece of protoplasm and point to the iron or chlorine that it contains. No, the iron and the chlorine and all the other elements in the protoplasm are so combined that they lose their individual properties.

Just as our foods must contain carbon, hydrogen, oxygen and nitrogen not merely to supply the necessary energy, but also to build or rebuild tissue, so, in order to build or rebuild tissue, we must supply such elements as calcium, phosphorus, sodium, etc.; for these elements just as surely enter into the composition of living matter. It is these elements—calcium, phosphorus, etc.—in various chemical combinations, that constitute the ash or mineral matter.

I should, of course, qualify my statement somewhat when I speak of the composition of living matter. Strictly speaking, we do not know the composition of living matter. Every time we submit protoplasm to chemical analysis, those familiar properties which *in toto* manifest themselves to us as "life" disappear. All that we can say is that the probabilities favor the assumption that while the internal arrangements of the molecules in living matter are different from matter which is no longer "living," the elementary composition of both remains the same.

How Mineral Matter Functions. While an im-

portant function of the mineral matter in diet is to supply certain necessary elements that go towards building protoplasmic material, the mineral matter performs other functions equally important; but most of these are of such a nature as not to be very easily intelligible to the layman. In a general way, it may be stated that these mineral constituents play an important part in regulating the concentration of liquid within and without the cell, and in maintaining the body in a state of neutrality.

This last sentence sounds "technical"; but perhaps by amplifying it we can make it less so. Man is made up of millions of cells. These cells are bathed by the lymph and blood which bring food to the cells and carry away the waste material. The cells and blood and lymph may, for our purposes, be considered as liquids in which solids are dissolved—in some such way as the liquid water can dissolve the solid salt. As a matter of fact, physico-chemical studies of cells have shown them to be of far more complex structure than the last sentence would indicate; but no matter. The cells, you will remember, are pictured as more or less spherical in shape. If the liquid outside the cell contains much dissolved solid as compared to the amount of dissolved solid within the cell, the latter shrinks in size. If the reverse is true—if the liquid within the cell contains more dissolved solid than that without—the cell will expand and perhaps burst. In either case we reach an abnormal or pathological condition. It is only when the

amount of dissolved solid within and without the cell is equal, or, to put it better, when the pressure exerted within and without the cell is equal, that normal conditions are retained. The dissolved solids regulate these conditions; and the particular solids that are largely responsible for this regulatory mechanism are the mineral salts or "ash."

Body Neutrality. Another function of the mineral salts, that of maintaining neutrality, also deserves further emphasis. The cells are readily responsive to the slightest disturbances due to outside influences. Even slight changes in the cells may give rise to profound disturbances in the body. Usually an amount of acid is formed in the body which might do much harm to the cells and therefore to the body as a whole. In steps the mineral matter and neutralizes the acids. (It should be mentioned that other substances apart from mineral matter also show this property.) Of course there are cases where the mineral matter is powerless to do anything.

Salt. In some instances some very specific functions can be assigned to a number of the constituents of mineral matter, aside from the very general function of the latter of contributing to the structure of protoplasm. Salt (the ordinary "table salt") is one of these. When the masticated and somewhat chemically modified food finds its way into the stomach it there undergoes further changes, and one of the two important substances that bring these changes about is hydrochloric

acid. This acid, consisting of the two elements, hydrogen and chlorine in chemical union, is not a constituent of any of our foods, and therefore is not taken into our system. In fact, a concentrated solution of it is a decided poison, and a man contemplating suicide would be apt to think of hydrochloric acid as a means to that end. Yet one of the body's branch factories, situated near the lining of the stomach, manufactures a very weak solution of it for the purpose of helping the digestion of food.

The Acid in the Stomach. Many theories have been advanced to explain just how the body is capable of producing the hydrochloric acid, but none is very satisfactory. Since the acid consists of hydrogen and chlorine in chemical union, there must be a source of these elements in the body. There is; but just how, beginning with the raw material, we can produce the finished article, is a mystery. The source of the chlorine is salt, which itself consists of the elements sodium and chlorine chemically combined. This contribution to the formation of acid in the stomach is a very important function of the salt we eat.

An Illustration of Chemical Action. It may be of interest, as illustrating just what a chemical action may involve, to say a word or two about the salt. Salt, as we have said, is composed of the two elements sodium and chlorine in chemical combination. The chemist gives the name sodium chloride to salt so as to indicate its composition by name. Sodium itself is a lustrous, grayish-white

metal, extremely poisonous, and reacts violently with water the minute it comes in contact with the liquid. Students are warned to store their sodium in bottles containing kerosene. They are also warned to handle the metal with forceps and not with the fingers, and to be careful never to bring it in contact with any water, except under carefully regulated conditions. Chlorine, the other constituent of salt, is a light-yellow gas, of suffocating odor and very poisonous. Its extensive use on the western front in the earlier days of the war is only too well known to this generation. Yet here are these two elements, the one a poisonous solid and the other a poisonous gas, which can be made to unite with one another to give you sodium chloride or salt, which in appearance does not in the least suggest sodium or chlorine, and which has not only the negative virtue of being non-poisonous, but the positive one of being an absolutely indispensable article in our diet.

Though salt, like the other mineral constituents, is present in the foods we eat, it is one of the very few that we deliberately add to the diet. We use it and say that it gives *flavor* to the food. So it does. But you see now that its function is not limited to that of a mere condiment.

Calcium and Phosphorus. The skeleton of bone largely consists of a substance to which chemists give the name calcium phosphate, which, judging by its name, evidently contains calcium and phosphorus. Here, then, we can point to a very important function of these two elements. We may

add one or two others. If you cut yourself so that blood comes to the surface of the skin, why does blood continue to flow only a little while and then stops altogether? (I am here ignoring very serious injury.) You will notice, if you have the courage to watch nature's operation closely enough, that the blood eventually forms a clot and so fills up the leak. This clotting or "coagulation" of the blood would be impossible but for the calcium present. To be sure, clotting is a process that involves more than the participation of calcium, but this element is necessary.

A number of very complicated substances—the *phosphatids*—are found in larger quantities in the brain than in other parts of the body. Though we do not know just what the phosphatids do, the mere fact that they are present points to a probable function; but the fact that they are in such abundance in brain tissue particularly, implies that a phase or phases of brain activity may be associated with their presence. The name phosphatid will possibly suggest to the reader that it is derived from the phosphorus it contains. Phosphatids do contain phosphorus.

"Phosphorus for the Brain." Since phosphatids contain phosphorus, and since phosphatids are present in large amounts in the brain, it was somewhat natural to assume that by increasing the amount of phosphorus in the food, mental development might be influenced, possibly accelerated. All experiments in this direction have failed to confirm such an assumption. Nevertheless, the

idea was sufficiently attractive to quacks and their advertising agents for them to seize upon it and create the slogan "phosphorus for the brain."

Phosphorus is essential; a certain minimum quantity must be present; but it does not necessarily follow that a surplus over the minimum can be used to advantage.

When we speak of phosphorus as being an essential in diet we do not mean the element in the free state. We never do mean the elements in the free state. Phosphorus is a poison. "Phosphorus poisoning" is quite common in match factories. But just as carbon is essential not in the form of coal, but in the form of some "food" containing it "in chemical combination," so phosphorus is utilized only when presented in "chemical combination" with other elements. Oxygen is the only element in the free state that is utilized by the body.

Iron is another essential constituent of the diet. It is needed to supply the iron present in hemoglobin, the red pigment of the blood. "Eat iron and you will be strong"—another one of those pieces of advice offered by quacks to credulous people. If you are anemic, iron in the form of one of its compounds, particularly such as are found in our foods, may be of some benefit; but far more important is to readjust your manner of living. A wholesome diet, plenty of sleep and plenty of fresh air, will do more to rebuild your red-blood cells than any of the iron tonics that have ever been invented.

A Comparison of the Behavior in the Body of Mineral Matter and the Organic Foodstuffs. A feature which sharply distinguishes the behavior of mineral matter from that of fat, carbohydrate and protein, is that the former undergoes no change prior to absorption by the blood. Your salt, for example, passes from the mouth to the stomach, and then into the intestine, and is there absorbed through the walls of the intestine, finding its way directly into the blood stream—the blood in turn carrying the salt to the various tissues of the body. The fat, protein and carbohydrate, however, undergo extensive alterations before the blood gets hold of them. The process of digestion is the process of converting the fats, proteins and carbohydrates into such a state as to make them fit for absorption by the blood. When you suffer from indigestion, that usually means that the workmen in the digestive tract—known as "enzymes"—responsible for the preparation of the foods in a form capable of assimilation by the blood, are either sick in bed, or too tired because of twelve-hour shifts (due to excessive eating), or are out on strike because of low wages (perhaps due to underfeeding).

CHAPTER V

WATER AND OXYGEN

Water. The struggles in life are largely struggles to satisfy part of our food requirements. The other part the slum dweller gets as easily as the owner of a Fifth Avenue mansion. That "other part" is water. Perhaps some day our food speculators will have studied the science of nutrition sufficiently to realize that water is as much a food as meat and butter and eggs; then they will tax their ingenuity to devise a means by which the production of this valuable liquid can be controlled, or its output restricted. But I must not put the speculator on this scent.

Abundant in quantity, and reaching the consumer at little or no cost, few of us ever include water in our list of foods; yet it is common knowledge that you can forgo eating longer than you can drinking. Water does not undergo any such changes in the digestive tract as do fats, proteins and carbohydrates; it is in fact absorbed and assimilated by the system without any change—like salt; and like the latter, yields no available energy. Its extreme importance arises from two facts: in the first place, a large percentage of living matter

consists of water; secondly, the various phases of cellular activity require water as a medium. We are told that "all physiological actions have their seat in systems containing water as an essential element"; which, translated into our everyday language, means that life would be impossible without water. Thales, the ancient Greek philosopher, appreciated this when he formulated his system of philosophy in which water was made the origin of all things. Even our good friend Aristotle made water one of the cardinal points of his system of the universe. It is only in our own day that our indifference to the liquid has become so apparent, and that in place of it we have come to worship the cocktail, which, nevertheless, may contain over 90 per cent of water.

Our water requirement we get in several ways. Plebeians get it largely from water direct. Almost all of us get some, and many of us get most of our water from beverages. But all of our solid foods contain water. Some, such as fruit and many vegetables, may contain as much as 80 to 90 per cent of the liquid. That is why the calorific expert claims that you do not get your money's worth by eating fruits and vegetables. Our later chapters will show that the calorific expert will need to revise some of his opinions.

Oxygen. In our discussion of calories, we emphasized that our source of energy arises from the burning (or combustion, or oxidation) of foods in our system. This burning, as was pointed out, is impossible without the presence of oxygen (or

air, which contains oxygen), just as oxygen is needed to burn a candle.

If by a food we mean a substance which supplies or helps to supply energy, or one which repairs the waste of tissues and provides raw material for growth, or a substance which serves both these functions, then oxygen is most certainly a food. Absorbed by the lungs from the air and taken up by the red blood cells in the blood, the oxygen is distributed to the cells of the body, and there the oxidations take place.

The consequences of a lack of oxygen supply are soon apparent. Sometimes the individual may be surrounded by plenty of air, but his bodily machinery may be in such poor condition that he finds it difficult to assimilate the necessary supply. The disease known as asthma may serve as an example. Sometimes again the supply of air may be limited. Again a gas may be present in the air of which the red blood cells may be fonder than of oxygen. Cases of asphyxiation come under this heading. Here one of the products of the incomplete burning of coal in the stove, carbon monoxide, fills the room and finally enters our blood, which seems to have a greater "affinity" for it than for oxygen. But carbon monoxide cannot substitute for oxygen in the burning of foods; so death results.

"Fresh" Air. Since the need for "air" is primarily our need for oxygen, the question arises, why the desire for *fresh* air? Does such air contain more oxygen than the air of a well-ventilated room? That cannot be, for the percentage of oxy-

gen in each is the same. Have the other constituents of the air an influence? No doubt, but the most careful chemical and bacteriological analysis fails to distinguish the air outside from the air in a well-ventilated apartment. "A partial explanation" [of the obviously beneficial effects of fresh air], writes Professor Bayliss, "may be, as Leonard Hill contends, that the effect [in a room] is due to the absence of currents of air and the stimulation of the skin produced by them. It would thus be a result of failure of stimulation of the nervous system. The general experience of more refreshing sleep obtained when the bedroom window is open tends to support the view of the importance of the effect on the nervous system. The benefit of a 'cold bath' is probably of a similar nature, as is also that of 'exercise' to a certain extent."

Condiments, Flavors and Stimulants. Look into a rotisserie window and notice how "it makes your mouth water." Making "your mouth water" is a fact, not a fiction. Psychical influences in stimulating digestion are extremely important, as innumerable experiments have shown. These psychical influences may stimulate digestion by stimulating the secretion of digestive juices—the fluids responsible for so altering the food as to make it fit for absorption by the blood and the system as a whole.

Often enough we get no psychical reaction after surveying the dishes spread on the table. Pot roast may not be a relishing dish to some. To make it more so we may do one of several things.

We may add a little mustard or a little ketchup to our pot roast; or we may eat it with some pickles; or we may add some salt and pepper. Perhaps none of these additions serves the purpose. If so, another dish has to be substituted. But very often the mustard or pickles, etc., do help. Any one of these additional substances helps to do what the mere looking at an appetizing dish will do—increase the flow of digestive juices. The primary function of these flavors and condiments is to make the food more appetizing.

Slightly removed from the substances just described are the stimulants, of which tea, coffee, cocoa, meat extracts (beef tea, beef juice, etc.), and, above all, alcohol are examples. They too—particularly alcohol—stimulate the flow of the digestive juices. With some of them, as with tea and coffee, the stimulation is due to the presence of an alkaloid, and alkaloids are distinctly injurious when taken in large quantities; hence the advisability of moderate tea and coffee drinking.

Very few of these substances add much to our calorific needs or to our requirements for tissue repair; though cocoa, with its relatively large quantity of sugar and fat (in the milk), and beer do give appreciable energy values. But notice that the calories are not derived to any extent from the stimulant itself, but from the substances mixed with the stimulant or condiment.

Alcohol. The best known, the best hated and the best loved stimulant is alcohol (the "grain" or drinking alcohol as distinguished from the wood

alcohol). Some who see in alcohol only a substance which has been invented to curse mankind, refuse to include it in a list of stimulants; and the weight of much medical authority favors such an exclusion. On the other hand, in diseases such as pneumonia, its beneficial effect has been amply proved. But that, say its opponents, can be said of all medicines; for they all help in small doses and injure in large.

A small amount of whiskey or a couple of glasses of beer a day have not been shown to have any evil effects on the normal, healthy individual. You may argue that this is merely a negative virtue. But the moderate drinker claims more for his alcohol. He insists that it serves as an excellent appetizer, and his experience leads him to contradict some of the learned doctors. He tells you that the little alcohol he consumes gives him an optimistic view of life, which not all the bungling of politicians can destroy.

The case is quite different with excessive alcohol consumption. Here the facts point to but one conclusion: alcohol in excess is a poison. Autopsy examinations have proved this beyond the shadow of a doubt. You may find impairment of the stomach, of the heart, and above all, of the nervous system. But why wait for these discoveries until death overtakes the sufferer? The results of excessive alcohol consumption on the individual while still alive are only too obvious to the onlooker.

CHAPTER VI

AMINO-ACIDS

Having surveyed rather rapidly the various substances that function as foods; having shown that the calorific value gives incomplete information; having shown the importance of a judicious distribution of food among the three classes of foodstuffs; having pointed out the importance of mineral salts, of water, of oxygen, and, to a lesser extent, of condiments, flavors and stimulants, it now becomes important to investigate some of these factors a little more carefully.

During the last twenty, and largely during the last ten years, research work in nutrition has revolutionized that science no less than the study of radioactivity has revolutionized our conceptions of matter. This and subsequent chapters will deal with these revolutionary changes—changes made possible very largely by the labors of American men of science.

How the dawn of the modern era arose is an interesting bit of history. It centers itself around a study of the protein food.

Gelatin. Early in the last century, long before a science of nutrition had been founded, the im-

portance of protein in the diet was recognized. But so also was the recognition that protein is the most expensive part of the dietary. Meat, which is largely protein, became a luxury beyond the reach of the poor during the stirring days of the French Revolution and the years that followed. What was to be done? The people had to have meat because it contained protein, but perchance there were substances other than meat that contained this precious nutrient? Others were known, such as the casein in milk and the albumen in egg, but eggs and milk were, if anything, even more expensive than meat.

Then a happy idea struck the scientists of the French Academy. Were there not enormous quantities of bones discarded yearly out of which gelatin could be extracted, and was not this gelatin a protein? Behold the panacea! D'Arcet invented an economical method for extracting the gelatin, and a committee of the Academy of Medicine, in solemn session assembled, declared the process and the food all that could be desired.

The learned Academy's report was published in 1814. On the strength of this report the French Government began their experiments at the hospitals. Why sick people rather than criminals were selected is not clear. To-day when the United States Department of Public Health desires to experiment with people, it usually turns to Sing Sing and places of that kind; and then the experiment is conducted with volunteers only.

The sick people in some of the French hospitals

were given gelatin in place of other proteins. They digested it easily enough; gelatin jellies in fact are easily digestible. But after a time the sick people fell sicker,—in such numbers and under such conditions that only the change of diet could account for it. Like the politician who is the hero to-day and becomes the traitor to-morrow, poor gelatin was thrust from its lofty pedestal back into the refuse from which it had been rescued.

But what was the matter with gelatin? Why could not this protein substitute the proteins in meat, egg and milk? Years elapsed before a satisfactory answer was found. At any rate, the world in the meantime learnt the lesson that merely giving a man 100 grams of protein without specifying the kind of protein meant no more than giving a man food yielding a sufficient number of calories, without, however, specifying how the food was to be distributed among the classes of foodstuffs. But life on this earth continued, and many died and many more were born, because instinct and experience led us to do the things we did do. To find an answer to the question why one protein is less nutritive than another requires an examination of the fate of the protein after it has entered the system. But here the earlier investigators suffered from the drawback that they were ignorant of the chemical constitution of proteins, and were therefore ill-equipped to study the changes of the protein in the system.

Amino-Acids. It was subsequently discovered—

by Emil Fischer * and others—that the proteins are made up of chemical units in much the same way that words are made up of letters; and just as the twenty odd letters are sufficient to form the many different words in our language, so the eighteen or more chemical units, obtained by analyzing proteins, are sufficient to form the different proteins with which we are familiar. These chemical units are known as *amino-acids.*

When a protein such as is found in meat is eaten, the several juices act upon it and break it up into its amino-acids. We have learnt that this breaking up of a protein in the digestive tract is a necessary prerequisite to absorption and assimilation. The system cannot absorb protein as such.** Introduce protein directly into the blood and it acts like a poison; but introduce the amino-acids out of which the proteins are built, and all goes well.

The factories in which the protein is prepared for absorption are the stomach and the small intestine. Here the proteins are changed to amino-acids, which then find their way into the blood stream, and thence to the cells.

In the cells occurs the reverse process of what takes place in the digestive tract; instead of breaking up proteins into amino-acids, the latter are

* Professor McCollum suggests that "Kossel's name be substituted for Fischer's, since Kossel did so much more pioneer work in showing the nature of the protein molecule and in the discovery of four amino-acids, whereas Fischer only discovered one. I have felt that more credit is due to Kossel than is usually given him."

** A little may be absorbed unchanged, but the amount is negligible.

joined together to form proteins. Analysis gives place to synthesis.

But why this breaking down of proteins into their units if these act merely as nuclei for rebuilding protein? A perfectly fair question. But remember that we are not rebuilding the *same protein*. The same letters will give you different words, depending upon the arrangement of the letters. The same bricks will give you different houses, depending upon the arrangement of the bricks. The same amino-acids will give you different proteins, depending upon the arrangement of these amino-acids. That is why the Germans call the amino-acids the *Bausteine* or building-stones.

Not all proteins contain the same amino-acids. Some proteins contain more of one amino-acid than another; others are deficient in one or more of the acids.

In order to build up that peculiar protein which we find in the tissues, the tissue protein, the cell selects those amino-acids it needs and discards the rest.

You may ask, why if what the cell needs is not the protein but the amino-acid, the diet should not rather consist of amino-acids, fats and carbohydrates, rather than proteins, fats and carbohydrates? Unfortunately, nature insists upon supplying us with the more complicated proteins; just why we do not know.* But nature has consider-

* This is not quite true. The physical chemist will tell you that proteins are colloids, whereas amino-acids are crystalloids, and there are reasons why plant and animal material should be in the colloidal state.

ately supplied us with a factory, known as the digestive tract, where the proteins can be changed into amino-acids.

But before we dismiss the general metabolism of proteins—the changes that substances undergo in the system—we must refer to another topic, because of its relationship to the subject of just how much protein the body needs. We have already seen in earlier chapters how the subject of protein needs has given rise to much discussion. Most of the experiments conducted in this direction have tended to point to an amount of protein considerably less than that ordinarily used by man. But the more recent studies have shown us that not all of the protein ingested is utilized by the cells. As we have just seen, only a select number of the amino-acids formed from the protein are taken up by the cells to form tissue protein; the rest are discarded. Is it not therefore necessary to eat more protein than would at first hand appear, if only to insure an adequate supply of those amino-acids needed for tissue building? Arguments such as these have led to the revision of the diets of our soldiers in favor of a relatively high protein content.

Why Gelatin Is a Poor Type of Protein. But now it is time to turn back to our gelatin. A careful analysis of this protein has shown that two of the commonest amino-acids—so common that they are found in most of the other proteins—are missing in gelatin. These amino-acids are known by the high sounding names of tyrosine and tryptophane.

Might not these two amino-acids be essential to tissue up-building? Might not the absence of these two amino-acids explain the inferiority of gelatin to other proteins?

If such a view is sound it should be capable of being put to the test of experiment. And surely enough, where gelatin (plus fat plus carbohydrate plus mineral salts, etc.) alone was found to be inadequate to sustain animals, the same diet to which the two amino-acids tyrosine and tryptophane were added, met all requirements.

In this experiment, based on the laborious work of many scientists stretching over a decade, is to be found the key to much present-day activity in the science of nutrition. It has led to an entire revision in the feeding of armies and nations. This will be made clearer as we go on.

Though there are some eighteen amino-acids known which, in varying proportions, make up the composition of the different proteins, only the influence of three or four of these acids on the diet has so far been at all extensively studied. But a study of the influence of these three or four has already afforded us some amazing results.

The Amino-Acid Content of Proteins. Let us present the reader with some quantitative studies. Turn to page 189 and examine the percentage of amino-acids isolated from various proteins.

What does such a list show? Some of the proteins do not contain the amino-acid glycocoll; others do not contain tryptophane; still others are deficient in lysine and cystine. (Strictly speaking,

it is incorrect to speak of a protein as "containing" such and such amino-acids. These amino-acids become evident only after the protein has been decomposed.) To what extent are these amino-acids needed by the organism, and what happens if the only source of protein in the diet is deficient in one or more of these amino-acids?

The answer has already been supplied for gelatin. Unless the missing amino-acid tryptophane (and tyrosine) is added, death occurs.

Now suppose we arrange a diet in such a way as to vary from time to time the protein it may contain. Let us assume that we have fixed upon the type and amount each of fat, carbohydrate, mineral salts; and that we allow plenty of water and plenty of air; and that we adhere to such a diet throughout the series of trials. From time to time, however, we shall replace one protein, say casein, with another, say zein. If the substitution of zein for casein causes ill-effects, we may reasonably assume that this is due to the absence of one or more amino-acids from the diet. Suppose we add one or more of such amino-acids to this otherwise deficient diet and the animals that we experiment with begin to thrive again; are we not justified in concluding that our assumption was correct?

This, in fact, is the procedure that Professor Hopkins of Cambridge, Dr. Osborne of the Connecticut Experimental Station and Professor Mendel of Yale have adopted. The last two investigators in particular, who have done all their work jointly, have enriched this phase of the science with much

of value. Let us follow Osborne and Mendel in their path.

Drs. Osborne and Mendel's Experiments. They selected white rats for their experiments, for a number of reasons. Rats are small, easy to handle and multiply rapidly. They usually live not more than three years and "280 days suffices to complete the entire period from growth to maturity"; which means that several life cycles can be watched. Not only does the rat come under observation during a period which would correspond to about 60 years in the life of man, but the effects of the diet on the offspring may also be noted. In fact, several generations are included in such a survey.

Now what was to constitute health and what ill-health? In the infant a steady increase in weight is taken as the best criterion of normal development. Of course we cannot always be sure that an increase in weight means just this, but in a large percentage of cases it does; and it becomes a simple way we have of measuring progress. A certain sign of the sick man returning to a state of normality is when he gains weight. We say he "puts on flesh." Under normal conditions the adult neither gains nor loses.

How to "Plot" Curves. Drs. Osborne and Mendel adopted this standard of measuring progress by noting the increase in weight of their rats.

To present their results graphically in a way that a mass of figures never could, they plotted curves in much the way that nurses in hospitals and the "modern" mother do when they wish to keep an easily presentable record of their infants' gain in

weight from week to week. Such a nurse or mother first records in her notebook the various dates and corresponding weights of the child. Thus, to take an example, we may find some such record as this:

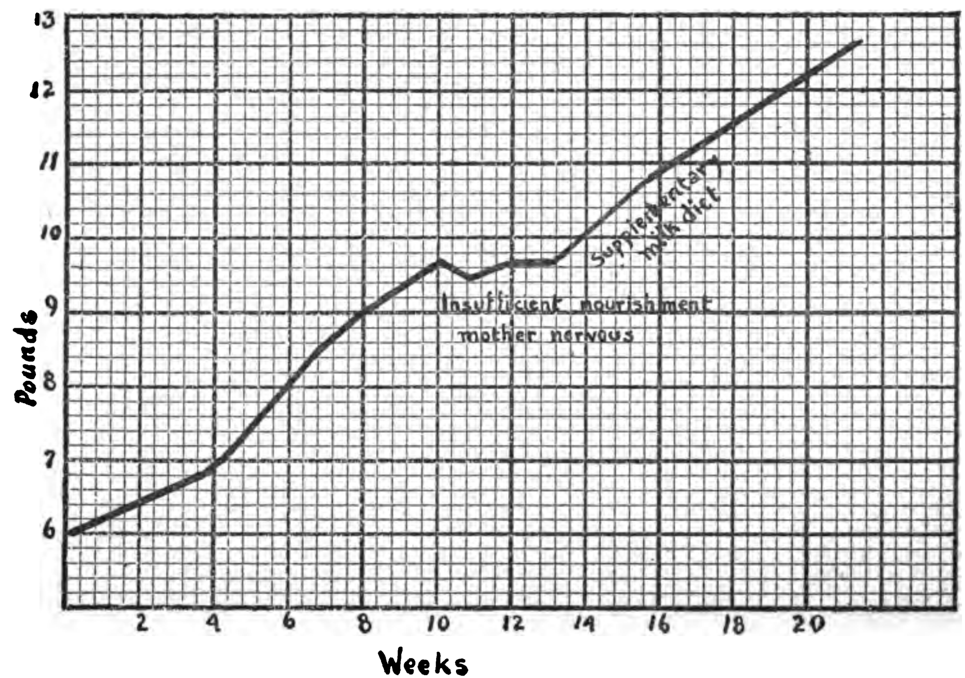
Week	Weight			
At birth	6	pounds	1	ounce
At the end of the first week	6	"	4	ounces
At the end of two weeks	6	"	10	"
At the end of three weeks	6	"	15	"
At the end of four weeks	7	"	4	"
At the end of five weeks	7	"	13	"

and so on. Now she takes her square-lined paper and marks off suitable horizontal spaces to indicate time and vertical spaces to indicate weight. A convenient way she finds is to call every seven squares in a horizontal direction one week (7 days), the number "1" at the end of the first seven squares indicating one week, "2" at the end of the first fourteen squares indicating two weeks, and so on. Similarly along the vertical line, since she deals with pounds and ounces, she selects sixteen squares to represent one pound; so that at the end of the first sixteen squares she puts the figure "1," representing one pound; at the end of thirty-two squares she puts "2," representing two pounds; and so on.

At birth (zero week) the child weighed 6 pounds 1 ounce. You travel vertically until you reach the figure 6 and then you go one square more. You make a cross at that point. At the end of the first week the child weighs 6 pounds 4 ounces. You

FIGURE 1.—GROWTH OF AN INFANT

For an explanation of this chart, see page 60 of text.



Pounds
13
12
11
10
9
8
7
6
2
4
6
8
10
12
14
16
18
20
Weeks
Insufficient nourishment
mother nervous
Supplementary
milk diet

travel horizontally until you reach "1" (one week) and vertically until you reach "6," and then go four squares above that (to represent 4 ounces). You make another cross here. And you continue that from week to week. Then you draw your line through the intersection of your crosses and you get a curve such as is shown in figure 1.

What do you gather from such a chart? So long as the curve is up an incline, so long as you are traveling up-hill, the child shows a constant increase in weight, and therefore represents a probable normal development. The steeper the incline the more rapid the increase in weight. But where the slope reverses and goes down, instead of up-hill, the curve represents a loss in weight and the child is therefore not developing as well as it should be.

From the curve under discussion (figure 1) you will notice that aside from a loss in weight during the first few days (a regular occurrence), the curve slopes steadily in an up direction until the tenth week is reached. Then there is a decline with the eleventh week. The doctor diagnosed the child's loss of weight as probably being due to insufficient nourishment, or perhaps to unwholesome nourishment,—because the mother was nervous. He suggested a supplementary milk diet. Notice how from the thirteenth week the curve starts up-hill again.

If I have dwelt for some time on this simple example, it is because once the reader understands the significance of such a curve as is represented in

figure 1, he will have no difficulty whatsoever in understanding the subsequent charts. And as has already been stated, this graphical method of representation has the advantage over mere figures in that you can take in an entire experiment at a glance.

Animal and Vegetable Proteins Compared. Now turn your attention to chart 2. A diet consisting of the protein casein* (found in milk) which, as you may gather from the table in the Appendix, does not contain the amino-acid glycocoll, caused rats to grow and gain in weight; for notice the incline of the curve marked "casein." Evidently glycocoll is not indispensable. When the protein gliadin (derived from wheat or rye) is substituted for casein, the incline of the curve is nowhere near as sharp. The increase in weight is very, very gradual. Gliadin, as the table shows, is deficient in the amino-acid lysine, and the failure to gain so rapidly may be due to this deficiency.

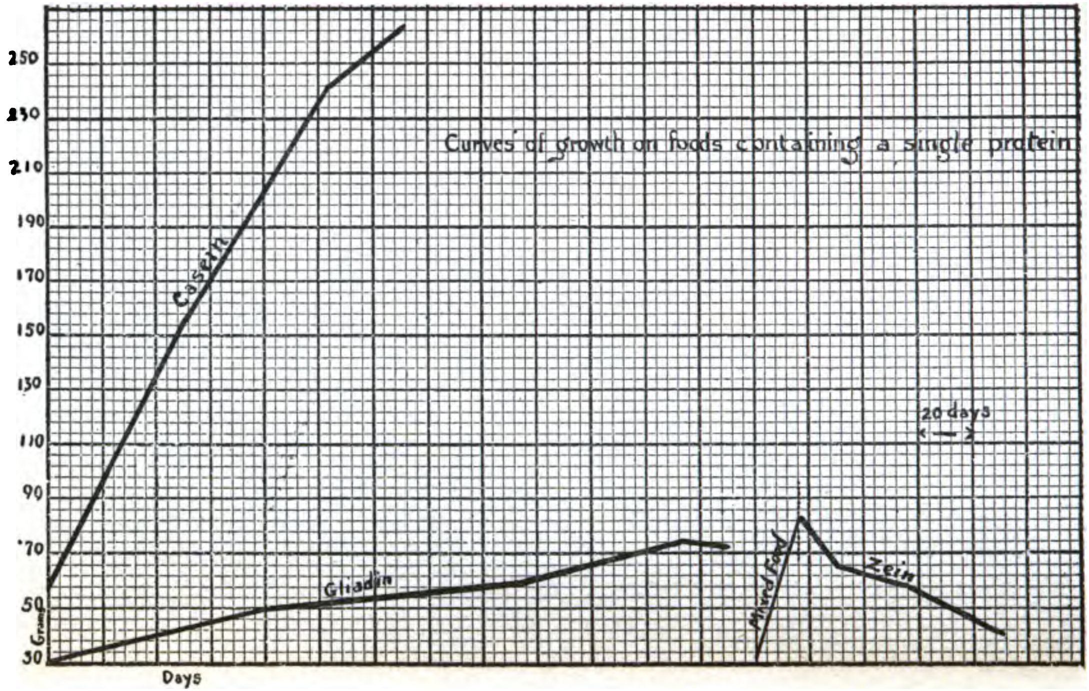
The foods other than protein that Drs. Osborne and Mendel used were starch, sugar, lard, agar and inorganic salts. The agar was added "to form an indigestible intestinal 'roughage,'" and the inorganic salts were given either as a mixture of the pure inorganic salts, or in the form of "protein-free milk"—a product representing the milk from which fat and protein have been removed. In their

* And, of course, fat, carbohydrate, etc. Please remember that in all the examples here given, the one constituent of the diet that varies is the protein; the other constituents are not changed during such experiments, though they are always added in proportions that experience has taught to be beneficial.

FIGURE 2.—AMINO-ACIDS AND GROWTH

Showing typical curves of growth of rats maintained on diets containing a single protein. On the casein food (devoid of glycocoll) satisfactory growth is obtained; on the gliadin food (deficient in lysine) little more than maintenance of body weight is possible; on the zein food (devoid of glycocoll, lysine and tryptophane) even maintenance of body weight is impossible.

Osborne and Mendel: J. A. M. A., 1915.


Curves of growth on foods containing a single protein
Casein
Gliadin
Mixed Food
Zein
20 days
Grams
Days
30
50
70
90
110
130
150
170
190
210
230
250

subsequent vitamine studies these investigators made frequent use of this "protein-free milk."

In answer to the criticism that "protein-free milk" is not free from nitrogen compounds, and "therefore makes a comparison of the biological value of different proteins" difficult, Prof. Mendel writes: ". . . It is true that protein-free milk which we used in our earlier experiments contained a certain modicum of nitrogenous matter—a fact which we ourselves pointed out. It is not unlikely that this may have altered the numerical values in the comparisons which we made earlier between the different proteins. In recent years we have no longer used this product. In fact at the present time whenever it is desired to compare protein values we employ a yeast concentrate which gives no biuret reaction [the 'biuret' test is one used to detect proteins]. I believe that the fundamental conceptions regarding the importance of certain amino-acids is unaltered by any of the comments which have been made."

Now notice the interesting situation that arises when zein (derived from maize) becomes the sole source of protein. At first the rats under examination were given a mixed food containing several different proteins, and the animals thrived splendidly. Then after about two weeks the diet was so changed as to replace the mixed proteins with the single protein zein. See how the curve suddenly swerves. It actually goes down-hill. This down-hill slope of course indicates that the animals are losing weight and are on the decline; for remember that we are

not dealing with rats that have reached maturity and that are merely too fat, but young rats in the growing stage. If rats in the growing stage lose weight, particularly if the loss continues over many weeks, then something is surely the matter—just as under similar conditions all would not be well with an infant.

Zein is devoid of the amino-acids glycocoll, lysine and tryptophane. The experiments with the milk protein, casein, have proved that glycocoll is not essential; for though casein contains no glycocoll, the animals thrived. Where lysine alone is deficient in the protein molecule there is more or less maintenance; that is, neither a decided increase nor decrease in weight (see the curve marked gliadin); hence the decided downward slope of the curve in the case of zein would lead to the belief that the indications of rapid decline are probably due to the absence of the amino-acid tryptophane (and perhaps also cystin. See later experiments).

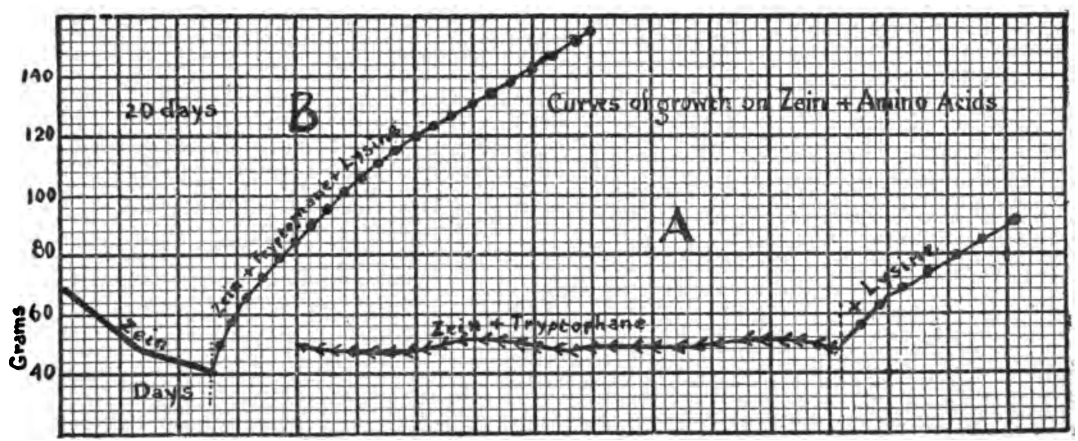
The three experiments just described are extremely suggestive, for they point to the indispensability of the amino-acids lysine and tryptophane. The indications are that no matter how many calories a diet yields, no matter how well the diet is distributed among the foodstuffs, no matter how much protein is given, *if the protein part of the diet is deficient in the amino-acids lysine and tryptophane, life is impossible.*

To prove this still further, Drs. Osborne and Mendel fed rats with a diet in which the protein consisted of zein only. Note the loss in weight

FIGURE 3.—AMINO-ACIDS AND GROWTH

Showing the effect of the amino-acids tryptophane and lysine to zein which fails to yield them. With zein alone there is nutritive decline. The addition of tryptophane permits maintenance but not growth. The addition of tryptophane *and* lysine enables the animals to make considerable growth.

Osborne and Mendel: J. A. M. A., 1915.

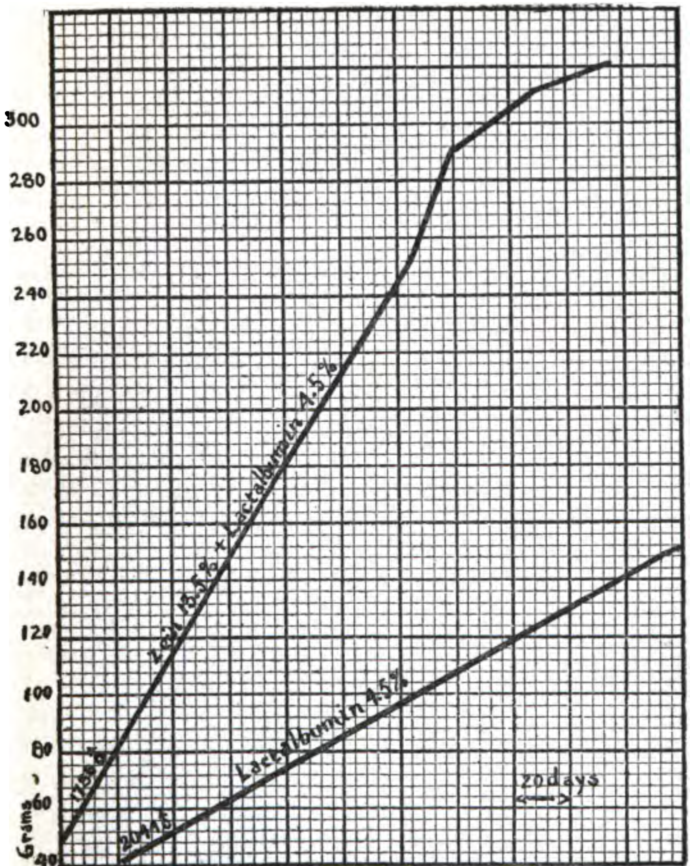


Curves of growth on Zein + Amino Acids
Grams
140
120
100
80
60
40
Days
20 days
Zein
Zein + Tryptophane + Lysine
B
Zein + Tryptophane
+ Lysine
A

FIGURE 4.—AMINO-ACIDS AND GROWTH

Showing the favorable effect on growth by supplementing a protein (zein) incapable of maintaining animals when it is the sole protein furnished in the diet with a more "perfect" protein (lactalbumin). The proportion of the lactalbumin used—4.5 per cent—was of itself insufficient to promote growth well. It evidently furnished the amino-acid groups lacking in the zein.

Osborne and Mendel: J. A. M. A., 1915.



300
280
260
240
220
200
180
160
140
120
100
80
60
40
Grams
Days
Zein 13.5% + Lactalbumin 4.5%
Lactalbumin 4.5%
20 days

(chart 3, the first portion of curve B). After several weeks the amino-acids lysine and tryptophane were added to the diet. See how the curve immediately shoots upwards. When tryptophane alone is added to the zein the rats neither gain nor lose in weight (chart 3, first part of curve A); upon the further addition of lysine a gain in weight is noted.

Enough now has been said regarding these charts so that charts 4 and 5 and 6 become self-explanatory. Chart 4 is of interest because it points to the advantage of a diet consisting of mixed proteins rather than a single protein; and our diets do happen to include mixed proteins. Charts 5 and 6 emphasize the importance of *appreciable* amounts of certain amino-acids, such as cystine (chart 5) and lysine (chart 6).

So far only a few of the amino-acids have been tested; but this is not surprising, for the experimental details of such a research often become bewildering even to the professional man. What is glibly dismissed in a sentence or two in some report, often represents weeks of painstaking labor. But the study of even these few amino-acids has made it evident that henceforth instead of speaking of the protein content of foods, we shall have to discuss them in terms of their amino-acid content.

So long as man eats food in variety and abundance, the fear of malnutrition is slight. Without really knowing the precise content of his food, he manages to get what he needs. But the days of

abundance for most of us are fast coming to an end. In certain portions of the hemisphere even mere subsistence is beset with great difficulty. If in the place of semi-guesswork we can substitute exact knowledge; if we can tell the people, Take such and such foods because they contain such and such proteins, which in turn are rich in such and such amino-acids essential to life, then we have contributed very definitely to the welfare of mankind.

The Feeding of Farm Animals. Of equal and perhaps even more immediate consequence are these studies to animal production in agriculture. Let me quote Drs. Osborne and Mendel: "Corn forms the cheapest basis for the feeding of farm animals in food production. Inasmuch as the rate of growth is limited by hereditary rather than nutritive conditions, it is futile to furnish more energy, and particularly more protein, than is essential for normal development. An inadequate but cheap protein can be supplemented advantageously by one which supplies the needed factors, that is, amino-acids. The relative economy of these additions of supplementary proteins to an efficient but inexpensive ration depends not only on their quantity but likewise on their amino-acid make-up. A very small addition of a protein like lactalbumin may be far more advantageous, when the cost per unit of gain is considered, than larger amounts of cheaper proteins which supplement less perfectly the amino-acid deficiency of the standard diet. It is perhaps not too Utopian to expect that the day

FIGURE 5.—AMINO-ACIDS AND GROWTH

When 18 per cent of casein (as the sole protein) is present in the diet, satisfactory growth is obtained. With 9 per cent of casein much less rapid growth ensues. That the insufficiency of the smaller amounts of casein is essentially due to its relative deficiency in cystine-yielding groups is shown by the marked accelerating influence on growth brought about by the addition of cystine to the food containing 9 per cent casein.

Osborne and Mendel: J. A. M. A., 1915.

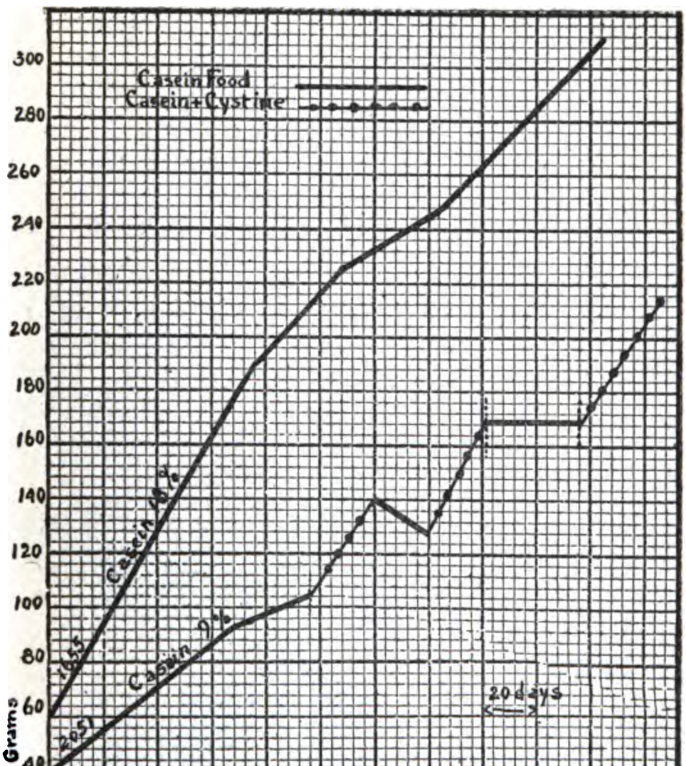
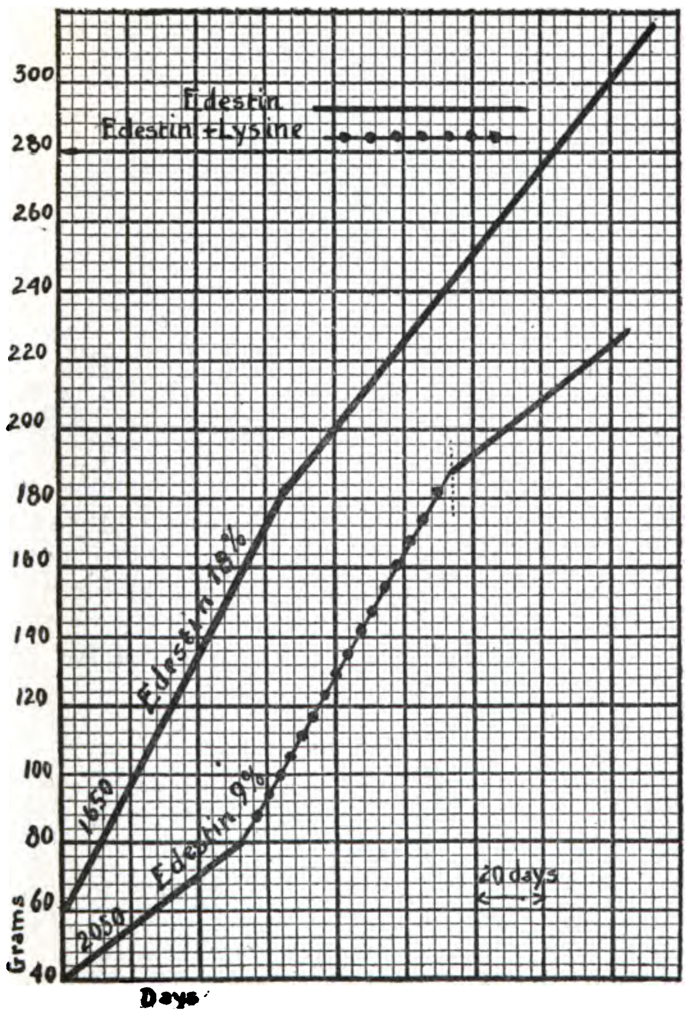

Casein Food
Casein+Cystine
300
280
260
240
220
200
180
160
140
120
100
80
60
40
Grams
Days
Casein 18%
Casein 9%
1655
2051
20 days

FIGURE 6.—AMINO-ACIDS AND GROWTH

The curve shows the satisfactory growth obtained when 18 per cent of edestin was present in the diet as the sole protein. With a smaller amount of edestin—9 per cent—much less rapid growth ensued. That the insufficiency of the smaller amount of edestin is essentially due to its relative deficiency in lysine-yielding groups is suggested by the marked accelerating influence on growth brought about by the addition of the amino-acid lysin to the food containing 9 per cent of edestin and the less rapid growth when the additional lysine was withdrawn from the diet.

Osborne and Mendel: J. A. M. A., 1915.



Edestin
Edestin + Lysine
Edestin 18%
1650
Edestin 9%
2050
20 days
Grams
300
280
260
240
220
200
180
160
140
120
100
80
60
40
Days

may come when amino-acid concentrates may serve to render perfect the mixtures of proteins in a fodder like maize or its commercial by-products."

The Biological Value of Various Proteins. The following among the proteins so far tried, when used in suitable concentration, have induced normal growth in rats. Evidently all the essential amino-acids in suitable proportions are present in these proteins:

Proteins of animal origin. Casein (found in milk); lactalbumin (milk); ovalbumin (hen's egg); ovovitellin (hen's egg). *Proteins of vegetable origin.* Edestin (hemp-seed); globulin (squash-seed); excelsin (Brazil-nut); glutelin (maize); globulin (cotton-seed); glutenin (wheat); glycinin (soy-bean); cannabib (hemp-seed).

Other proteins that have failed to induce growth are legumenin (soy-bean); vignin (vetch); gliadin (wheat or rye); legumin (pea); legumin (vetch); hordein (barley); conglutin (blue or yellow lupin); gelatin (horn); zein (maize); and phaseolin (white kidney bean).

All of the foodstuffs enumerated—milk, egg, wheat, etc.—always contain more than one of the proteins. So long as we eat mixtures of proteins we can know little of the biological value of each protein, except in rare instances, as in gelatin, which happens to be a homogeneous substance. Drs. Osborne and Mendel in the course of their various experiments have first very carefully *isolated* the various proteins from the foods.

Stunting. In connection with Drs. Osborne and

Mendel's work, we may note one other experiment of theirs, because it touches upon the nature of growth. A number of rats were given a diet of such a nature as to prevent any appreciable gain or loss of weight (see chart 3, page 71, the first part of curve A). This "maintenance" diet was kept up for 550 days. At the end of this period the diet was so changed as to include all the necessary amino-acids; in other words, this second diet was a "growth diet." The rats immediately began to grow and gain in weight. The amazing feature of this experiment is that these rats began to grow *250 days after they would normally have reached maturity;* for under normal conditions these same rats usually reach maturity at the end of 300 days. It is as if a boy had stopped growing when he was ten years old, and then by some freak would not continue his growth until he had reached his thirtieth year.*

Summary. To summarize the essential points that have been discussed in this chapter, we may say that—

1. Maintenance (neither gain nor loss in weight) and growth both require a complex of amino-acids. Maintenance requires, among others, the amino-acid tryptophane and probably some lysine; growth, that of lysine, and, to a lesser extent, cystine.

2. Proteins cannot be used interchangeably

* I must, however, add that recent experiments by Dr. Jackson do not wholly confirm Drs. Osborne and Mendel's conclusions. While growth can be resumed after prolonged stunting, such growth is not as rapid as under normal conditions.

with equal nutritive value. Their value to the body depends upon the kind and quantity of the individual amino-acids they contain. Because of this fact the problem of protein minimum resolves itself into a question of amino-acid minimum.

3. Stunting, whether by underfeeding in energy value of food supplied, by too low protein intake, or by absence of amino-acids necessary for growth, does not affect the inherent growth impulse.

It should be emphasized that these results have been reached by experiments on rats. How many such observations can be applied to man and his food cannot be stated with certainty; but if evidence were wanting that most of them are applicable, we need only point to the pitiable condition of many of the people in Europe. This condition is largely the result of poor nutrition or underfeeding. In either case amino-acids play an extremely important part. So do vitamines. But of that more anon.

CHAPTER VII

GLYCOGEN OR ANIMAL STARCH

The value of a protein we have seen is specified only when stated in terms of its amino-acid content. The protein itself is complex in chemical structure, but the units out of which it is built, the amino-acids, are relatively simple; and it is the latter that the body absorbs and assimilates.

The question now arises, Is what we have found for protein also true for carbohydrates and fats? Are these two substances also chemically complex, and is it probable that the body cannot absorb these substances as such, but rather as simpler units, the "building stones," out of which the more complicated material is synthesized? Have we, in other words, a something which is related to carbohydrate and another something which is related to fat in the way the amino-acid is related to protein?

Carbohydrates. Let us deal with the carbohydrates first. They are chemically a much simpler variety of substance than the proteins. Some of them, such as starch and cane sugar, are, however, still too complicated to be absorbed by the body without preliminary simplification. Others, on the other hand, are absorbed without any

change. Among the latter may be mentioned glucose and fruit sugar.

The Three Simple Carbohydrates. Now no matter what carbohydrate we eat, provided it is digestible—cellulose is an example of a carbohydrate which is not—and provided it needs further simplification before absorption, the juices in the digestive tract will always change it to one of three simple substances. Two of them have already been mentioned—glucose and fruit sugar. The third, galactose, is a product derived almost exclusively from milk sugar.

All carbohydrates then are changed, before absorption, to one or more of three substances: glucose, fruit sugar and galactose.* Here you see some analogy between these three and the amino-acids. But remember that we have eighteen amino-acids derived from proteins, in contradistinction to three "simple sugars" derived from complex carbohydrates; which immediately conveys an idea of the greater complexity of the proteins.

But if the three simple sugars bear some resemblance to the amino-acids, their behavior subsequent to absorption shows no such resemblance. You will remember that the amino-acids are taken up by the blood stream and conveyed to the various cells. There the cells utilize their property of selective action by selecting the amino-acids they need for

* Mannose and sugars known as the pentoses are sometimes present, but the occasions are rare. The pentoses are more abundant in the plant kingdom.

tissue up-building and repair, discarding the remainder.*

Glycogen. The three simple sugars, on the other hand, immediately proceed to the liver as soon as they are absorbed by the blood. There in some unknown way they are all converted to one substance, *glycogen or animal starch* (which also belongs to the class of carbohydrates). All carbohydrate food ultimately finds its way to the liver where it is stored as glycogen. Then whenever the body needs to expend energy, the glycogen reserve is immediately called into play. Through another mysterious process, the glycogen is converted back to glucose—but to glucose exclusively—which in turn is ultimately broken down to carbon dioxide and water, at the same time liberating energy in the form of heat. This conversion of glucose into carbon dioxide and water is a "burning" or "oxidation" process brought about by the cells. This process, like the formation of glycogen and the conversion of the glycogen to glucose, is still very imperfectly understood.

The value of a protein must be judged by the value of its structural units, the amino-acids; is the value of a carbohydrate to be judged by *its* structural units, glucose, fruit sugar and galactose? Is one of them more essential than another? Among amino-acids we have found lysine and tryptophane

* The discarded amino-acids find their way into the liver where, through a process of "de-aminization," part of the amino-acids are finally oxidized to carbon dioxide and water, yielding energy, and the nitrogenous parts find their way into the urine chiefly in the shape of urea.

to be much more important than glycocoll; can we say for example that glucose is more important than fruit sugar?

No definite answer to this question can be given; and this despite much clinical work on the subject. But it must be confessed that this phase of metabolism has not received as exhaustive a test as protein metabolism.

The Value of Milk Sugar in Infant Feeding. Still, some comments are necessary. In mother's milk we find milk sugar. This milk sugar is found in the milk even though no such sugar is included in the mother's diet. Evidently then the milk sugar is a product which the body can manufacture. Experience has shown that milk is the best food for infants. In this liquid the only carbohydrate present is milk sugar. This has led to the view that milk sugar is a much better carbohydrate for infants than other carbohydrates.

Still another reason has been advanced in favor of milk sugar. In the brain tissue are found a number of ill-defined substances, called cerebro-galactosides, which by special treatment the chemist can decompose into a number of substances, one of which is galactose (hence the name cerebro-*galactosides*). Much of what we knew of these substances we owe to Professor Gies. You will remember that galactose is one of the three simple substances into which all carbohydrates are changed before absorption. Now it so happens that among the carbohydrates we eat, milk sugar alone yields this galactose when acted upon by the juices in the digestive tract.

And milk sugar is found in milk. This has led some pediatricians to advocate milk sugar because of its possible function in the building up of brain tissue. But when we consider that galactose, like any other sugar, is converted to animal starch (glycogen) in the liver, and that then the animal starch becomes the source of the carbohydrate supply throughout the body, such a view lacks support.

On the other hand, eminent physicians are not wanting who are equally enthusiastic exponents of other carbohydrates in infant feeding. Some pin their faith to cane sugar; others to maltose; still other to starch and dextrin. The entire subject needs study of a much more exact nature.

CHAPTER VIII

SOAP AND GLYCERIN

The reader may wonder from the heading of this chapter what a cleansing agent and a source for explosives have to do with the foods we eat. We counsel patience.

Do you perhaps recall that story about the British scientists during the early days of the war when they were set to the task of utilizing all waste products? One of these products that received their attention was the discards from the soldiers' table; these discards contained fair quantities of fat. Whereupon our scientists separated the fat from the rest of the "rubbish," mixed the fat with a suitable alkali such as lye, boiled the mixture and eventually obtained soap and glycerin.

The process just outlined, whereby some kind of fat and some lye are heated, is the principle employed in the preparation of soap and glycerin on an industrial scale. But the juices in the digestive tract, which can change proteins into amino-acids and the more complex carbohydrates into a simpler variety, can also change fats into glycerin and soap. Not only can they do so, but they do do so. Our fats are never absorbed as such, just as our proteins

and our more complex carbohydrates are never absorbed as such. The fats are only absorbed after they have first been simplified by being changed into soap, glycerin and substances very closely allied, chemically, to soaps—fatty acids.

Glycerin is a very specific substance. When we say glycerin we have in mind one definite substance —just as definite as water. But the words "fatty acids" and "soaps" are of vaguer import; they include a class of substances, just as carbohydrates and proteins do. Among the fatty acids there are but three that interest us here, for they are the three that are physiologically important: stearic, palmitic and oleic acids. One or more of these three are formed (in addition to glycerin) whenever the digestive juices act on the fat of our food. By an extremely simple process—the action of alkali—some of these fatty acids are converted into soaps. The fats, therefore, before being absorbed are simplified into fatty acid, soap and glycerin. These three substances are absorbed, and for some mysterious reason are immediately reunited to form fat, which is then stored in the adipose tissues until the body has need of this source of energy.

Which among the structural units in fats is the most essential to maintenance and growth? Is glycerin more important than palmitic acid?

To form fat in the body both glycerin and fatty acid are necessary. The question that remains to be answered is, which of the three common fatty acids is the most important? This needs further study.

Are Fats Indispensable? In the meantime, another question presents itself. Are fats themselves absolutely indispensable in the diet?

We have pointed out in previous chapters that fats function as the fuel reserve of the body; first the carbohydrates are utilized, and then, when these are all exhausted, the fats are put to work. If we eat more carbohydrate than is needed for immediate use, the extra supply is converted into fat and stored as such.

But now would anything happen if we were to exclude fat from the diet? This experiment has never been carried out very successfully, for the reason that the means available to eliminate all fat particles from the diet remove substances other than fat. It is very much like trying to extract sugar from a mixture of sugar, salt and water. If water is the only suitable solvent you can employ, shaking the mixture with water will cause not only the sugar to go into solution, but also the salt.

Just how necessary the true fats are in the diet yet remains to be determined;* and until this is done we need trouble little about structural units in the fat molecule.

In the meantime, the attempt to extract fat from food by treating the food with a suitable solvent has led to unexpected results (see next chapter).**

* Drs. Osborne and Mendel have begun investigations in this direction.

** Closely associated with fat are a group of substances called lipoids that are found in every living cell, and whose function is still largely a mystery.

CHAPTER IX

VITAMINES

Milk, an excellent food for infants and growing animals, contains protein (casein), fat, carbohydrate (milk sugar) and inorganic salts. The protein if given in sufficient quantity contains all the needed amino-acids. Suppose that instead of supplying our animals with milk we feed them with the isolated constituents of milk, in quantity sufficient to supply fuel needs. We give our animals an excellent protein, plenty of fat and carbohydrate to supply energy needs, and all the mineral salts necessary. From what has been said so far, such a diet should comply with all requirements.

So indeed thought most scientists until Professor Hopkins of Cambridge disproved it.*

Professor Hopkins took two sets of rats—which we shall call A and B—in about the same stage of development, and of about the same weight, and fed A with the isolated constituents similar to those that can be obtained from milk (protein, fat,

* Dr. Funk calls my attention to the fact that as early as 1881—some years before Hopkins' experiments—Dr. Lunin made the statement that "substances other than casein, fat, milk sugar and salts are indispensable" (*Zeitschrift für physiologische Chemie*, volume 5, page 31, 1881).

FIGURE 7.—ABSENCE OF VITAMINES

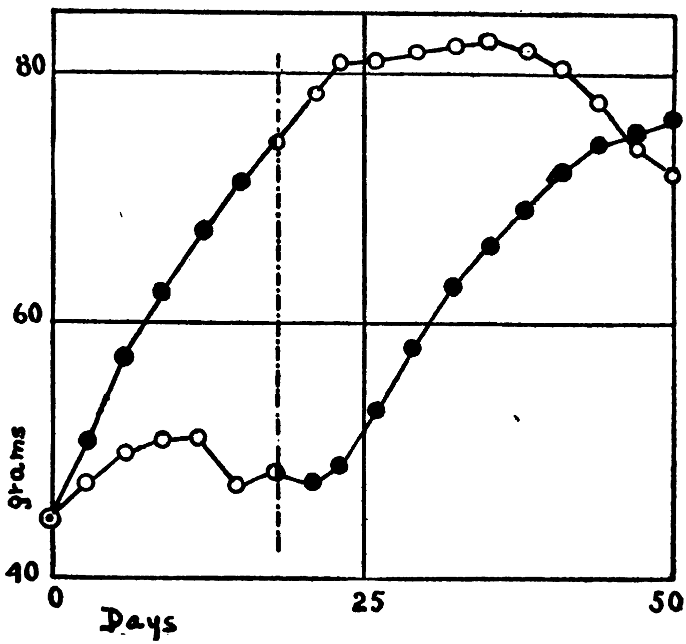
PROFESSOR HOPKINS' CLASSICAL EXPERIMENT

Lower Curve (as far as the 18th day)—Eight male rats on "synthetic" diet of protein, carbohydrate, lard and mineral salts.

Upper Curve—Eight similar rats taking, in addition, 2 cubic centimeters (two five-hundredths of a pint) of milk per day.

On the 18th day, marked by vertical dotted line, the addition of milk was changed from one set to another.

Bayliss: Principles of General Physiology.


80
60
40
grams
0
25
50
Days

sugar and mineral salts),* and B with the same substances plus a minute quantity of fresh milk.** The rats belonging to series A lost weight and showed decided pathological symptoms; those belonging to series B steadily gained in weight. On the eighteenth day the diets were reversed, so that now A was getting the little extra milk and B had theirs cut out. Almost immediately A began to gain in weight and B to lose in weight (see figure 7).

Let us examine the results of this amazing experiment. The isolated foodstuffs yielded energy in quantity more than necessary to satisfy all calorific requirements. The protein was rich in the necessary amino-acids. The mineral salts were not only abundant but various in kind. The fat and carbohydrate were there too. Yet all this was of no avail. The animals lost weight almost as rapidly as if they had been starved. When, however, a minute quantity of fresh milk was added—about two five-hundredths of a pint per day—the animals thrived.

The amount of milk added was so small that it could not have added anything material to the energy value of the food. Besides, the energy value of the foodstuffs was more than sufficient. And in so far as the most careful chemical analysis could show, the whole milk added was itself composed of

* The fat used was not milk fat but lard. This, as will be brought out presently, is most important.

** Plenty of water is always included in such studies.

nothing but protein, fat, carbohydrate and mineral salts, with the rest of it very little more than plain water. In other words, the chemical composition of the whole milk did not materially differ from the chemical composition of the constituents isolated from milk. Was the difference due to something in the milk other than fat, protein, carbohydrate and mineral salts? If so, this "something" must be present in exceedingly small quantities, since the addition of two five-hundredths of a pint of whole milk was sufficient to exhibit such striking effects.

Startling as this experiment seems, the result was not altogether unexpected by the scientist. He had already acquainted himself with a number of substances, present in minute quantities in the body, the absence of which caused profound disturbances to the system. Thus adrenalin, or as it is sometimes called epinephrin, is present in the blood to the extent of one part in one hundred million; yet it is said to be essential to life. The very ferments or enzymes that simplify our food in the digestive tract so as to prepare it for absorption, are present in exceedingly minute quantities; yet they are essential. If, then, there is some substance in food, present in microscopic amounts, without which life cannot continue, it was an interesting, though not wholly an unexpected discovery.

Vitamine. At this point we shall anticipate a little and state that the name *vitamine* has been given to the substance or substances—such as the

"something" in milk—which, though present in minute quantities in foods, are absolutely essential to a continuation of the life process.

The word *vitamine* was coined by Casimir Funk, a Pole. The first part of the word indicates its relation to the life process; the second, to its chemical nature. As we shall see, objections have not been wanting to the use of the word.

The Function of Vitamines. But what is the function of these vitamines? If fats and carbohydrates supply the fuel, and proteins the material for tissue supply, and mineral salts are needed for bone construction, etc., just what do the vitamines supply? We do not know. Some, such as Professor Gies, are of opinion that they supply the body with certain necessary chemical units which the body is unable to manufacture. Others—Professor Hopkins, for example,—regard these vitamines in the light of stimulators, in that they exert a stimulating influence upon the various activities of the body. But all this is intelligent guesswork and nothing more.

Now we must proceed to develop the whole subject of vitamines in such detail, and yet in so non-technical a way, as to convince the reader that, though no one has ever set eyes on a vitamine, vitamines are real things and quite indispensable as part of our dietary. We have been eating them ever since man and things that have life appeared on this planet; but we were ignorant of the fact. Like certain amino-acids (in proteins) which serve as indispensable units in the building and repair

of protoplasm, and which always formed a part of our diet even long before we were aware that such substances as amino-acids existed, so with these vitamines: we have used them always, but we have discovered them only within the last few years.

Stepp's Experiments. In 1909, some three years after Hopkins had begun the earliest of his experiments, Stepp, a German, turned his attention to the importance of the fat moiety in diets. He was particularly interested in certain very peculiar substances that are present in every cell and whose function is to this day very obscure: the lipoids. They are always very closely associated with the fats in food and living tissues. Wherever fats are, there are lipoids too; and the very solvents that remove fats remove most of the lipoids.

Stepp found that rats fed with bread made with milk throve and in time begot young that in turn developed quite normally. When the bread was first extracted with a mixture of alcohol and ether and the residue offered as food to the rats, the animals declined rapidly. Upon the addition of the alcohol-ether extract to the residue, the animals again began to gain in weight. Evidently the mixture of alcohol and ether extracted "something"—or more than one thing—which is a necessary constituent of food.

Since this ether-alcohol extraction may sound a little vague, let us turn to a simple experiment that may help to make this clear. In a dish we mix some sugar, sand and charcoal together. We next

pour some water into this mixture and stir. The chemist will tell you that neither the charcoal nor the sand dissolves in the water, and your own experience will corroborate such an assertion; on the other hand, the chemist knows and you know that sugar does dissolve in water. The effect then of adding water to the mixture of sugar, sand and charcoal is to *extract* the sugar from the mixture. And just as water extracts sugar from a mixture, so will alcohol, and particularly ether, or both ether and alcohol together, *extract fats and lipoids* from a mixture such as food.

When therefore Stepp found that bread made with milk was a wholesome food, whereas bread after extraction with alcohol and ether was not, he concluded that the cause of such a deficient food was due to the absence of fat, or lipoid, or both. He ruled out the protein because that is as little dissolved by alcohol and ether as is sand by water. He ruled out fat because the addition of butter fat to the residue left after the alcohol-ether extraction, failed to improve the condition of the rats. Neither did the addition of a variety of mineral salts help in any way. Aside from fat, the only other possible constituents in this alcohol-ether extract—in proportions at all appreciable—were the ill-defined group of substances known as the lipoids; and Stepp expressed the opinion that the absence from the diet of one or more of these lipoids gave rise to nutritive decline.

Without necessarily agreeing with Stepp's conclusion regarding the efficacy of lipoids, his experi-

ments did show quite clearly that something other than fat, protein, carbohydrate and mineral salts is necessary in an adequate diet; and in this respect Stepp's conclusions were in accord with those of Hopkins.

Drs. McCollum, Osborne and Mendel. Now come a few significant observations by Drs. McCollum, Osborne and Mendel. They found that an unwholesome diet with isolated foodstuffs in which fat was represented in the shape of lard, could be converted into a perfectly wholesome one by merely replacing the lard with butter fat. Lard, obtained from swine, is as much of a fat as butter fat or olive oil, or any other of the several varieties of fats and oils on the market. The differences among the fats are largely due to differences in quantity of the three fatty acids they usually contain. The differences can never be as profound as those between proteins, formed as the latter are from eighteen different amino-acids.

When, therefore, our investigators found the substitution of lard for butter fat to produce loss of weight and general decline in rats, they attributed the deficiency of lard not to the fat itself, but to a *something* accompanying the butter fat and not the lard.

This something, this vitamine let us call it, was being tracked to its birthplace. Hopkins' experiment had shown that milk contains a vitamine; but milk is a pretty complex fluid. Is the vitamine distributed evenly throughout the liquid, or is it confined to one or more constituents of the milk?

Stepp's work pointed rather vaguely to the fat; but our three American investigators converted this vagueness into reasonable certainty.

The Nutritive Value of Different Fats Compared. Osborne, Mendel and McCollum went even further. They showed that while the fat from egg yolk and codliver oil, and, to a certain extent, beef fat, could successfully replace butter fat, neither olive nor almond oil could; so that the latter two were no better than lard. And what was very significant in these experiments was that by the substitution of the vitamine-containing fat for the fat which evidently was vitamine-free, not only did the rats resume growth and gain in weight, but disorders due to malnutrition disappeared, and the general resistance of the rats to disease increased.

That the deficiency of lard is not due to its manner of preparation, which involves steaming, and which might perhaps destroy the vitamine, was shown by Drs. Osborne and Mendel by heating butter fat with steam—an operation which did not make the butter fat any the less effective. Incidentally this indicated a surprising resistance of vitamine to the effect of high temperature. Experiments to be described presently will necessitate a modification of this view—at least, in so far as vitamines other than the one just described are concerned.

Vital to the organism as these vitamines appeared to be, they could not serve the place of a deficient supply of fat, protein, carbohydrate and

mineral salts. It is of the utmost importance to remember this statement.

For some time the results of our American investigators were taken at their face value, and the opinion was generally expressed that the vitamine, though not actually in the hands of the scientific police, was known to be hiding in the fat portion of the food.

Conflicting Observations. Certain clinical observations on such diseases as beriberi, to be discussed in the next chapter, also strongly supported the view that vitamine is necessary; but there was one sharp point of difference between the two schools. McCollum, Osborne and Mendel had repeatedly made the observation that butter fat is extremely rich in vitamine; but Funk now showed that butter fat had no power to cure beriberi, which, as will be shown later, is a disease due to vitamine deficiency. What was to be made of such conflicting observations? Were the experimenters at fault, or was there more than one vitamine?

Dr. McCollum Solves the Difficulty. The problem was attacked by Dr. McCollum. A synthetic diet which he had found amply sufficient to meet all requirements consisted of the following: casein (the protein obtained from milk) 18 per cent; lactose (the scientific name for milk sugar, which belongs to the class of carbohydrates and is obtained from milk) 20 per cent; butter fat 5 per cent; salt mixture (meaning the mineral salts) in quantity and variety such as is found in milk,

and proved to be superior to Dr. Hopkins' original salt mixture; and starch (another carbohydrate) to make up 100 per cent. Water of course was offered a-plenty: as our scientist friends, fond of their Latin, are in the habit of putting it, *ad libitum.*

Polished rice, a term to be explained in the next chapter, was known to produce beriberi in men and similar diseases in birds. Rice, like all grain products, contains a large percentage of carbohydrates, chiefly starch; the polished variety as high as 80 per cent. McCollum now modified his synthetic diet in such a way as to add rice to it, but subtract the starch and milk sugar; so that the proposed diet consisted of rice, casein, butter fat and salt mixture. He reasoned that the rice contained more than enough starch to take the place both of the starch and the milk sugar in the original diet. But with this modified diet his animals developed beriberi symptoms.

This was rather perplexing. The experiment confirmed Funk's assertion that butter fat could not cure the disease, for the diet included ample proportions of this fat. On the other hand, butter fat in the original synthetic diet, had been shown to be the cause of renewed growth and general development in rats.

McCollum very carefully went over his data. The only substance that was not included in his modified diet that had formed part of his original synthetic diet was milk sugar. He had no reason to believe that milk sugar as a carbohydrate was

in any way superior to starch. But perhaps after all it was? Or perhaps, still more likely, this sugar contained vitamine, not necessarily identical with the vitamine in butter fat, which had the power of curing beriberi, just as the butter fat vitamine had the power of promoting growth?

And truly enough, when milk sugar was included in the diet of the sick animals they very soon recovered.

McCollum next showed that by very careful purification of the milk sugar he obtained a product which could no longer cure beriberi. In other words, the purer the milk sugar the less efficacious the remedy! This clearly pointed to but one thing: that the cure was not due to the milk sugar, but to some impurity in milk sugar; and that this impurity could be removed by carefully refining the sugar.

That such a view was sound was proved when to a diet including the purified milk sugar, which had no curative power, the washings containing all the impurities that had been removed, were added; the cure was immediate and effective.

How small in quantity the vitamine present as an impurity in the lactose actually is, may be judged by the following: The milk sugar used by Dr. McCollum was manufactured by Kahlbaum, a concern renowned in the scientific world for the purity of its chemicals. After further treatment by McCollum, chemical analysis failed to show any material difference between the original and the treated sugar. Yet something must undoubtedly

have been removed, for, biologically, the two sugars acted so differently; and to escape detection, this something—our vitamine—must have been present in exceedingly minute proportions.

Two Distinct Vitamines. Clinicians and physiologists had arrived at one conclusion: a factor other than protein, fat, carbohydrate and mineral salts is necessary. This factor they called vitamine. But McCollum now showed that there are in fact two distinct factors, two distinct vitamines at least, and that "the substance which relieves the condition of polyneurites in pigeons (comparable to beriberi in man) is always present in preparations which render the purified food mixture capable of promoting growth."

This last statement is very important. Says McCollum, if you think that in our earlier experiments with butter fat versus lard the only thing that mattered is the vitamine in the butter fat, you are much mistaken; there was the other vitamine, present in my milk sugar (and as we shall show, in other food products) that played an equally important part; for it prevented beriberi. It was there, but you and I were not aware of it.

Fat-Soluble A and Water-Soluble B. Later on Dr. McCollum and others showed that wheat, and particularly yeast, was very rich in this second vitamine, which we shall call water-soluble B, in distinction to the first vitamine, which we shall call fat-soluble A. The naming of these two vitamines is due to McCollum.

To illustrate still further this water-soluble B

factor, I shall describe a short experiment taken from Professor Hawk's book.* Two white rats from one to two months old and weighing from thirty to sixty grams (one to two ounces) are fed on an adequate synthetic diet consisting of casein 20 per cent, butter fat 15 per cent, starch 56 per cent, salt mixture (mineral salts) 4 per cent and yeast 5 per cent. The butter fat supplies fat-soluble A, and the yeast, water-soluble B. You will remember that in McCollum's early synthetic diet the water-soluble B was obtained from the milk sugar. In about two weeks the rats double their weight. Now the yeast (containing the water-soluble B) is eliminated. The food still contains sufficient energy-yielding material, sufficient protein rich in amino-acids, etc. You may, if you like, add even more casein or butter fat to the diet. The result is all the same: the rats lose weight. They lose weight so rapidly that in two weeks they drop from 80 to 60 grams.

By retaining the yeast in the diet, but substituting lard for butter fat, the influence of fat-soluble A can be illustrated.

For convenience we can summarize our results as follows:

	Vitamines A	Vitamines B	Growth
Purified protein + starch + inorganic salt + vegetable fat	−	−	−
" " " " " butter fat	+	−	−
" " " " " {vegetable fat and yeast	−	+	−
" " " " " {butter fat and yeast	+	+	+

*P. B. Hawk: *Practical Physiological Chemistry* (P. Blakiston's Son & Co., 1918), page 585.

FIGURE 8.—A SATISFACTORY SYNTHETIC DIET

ILLUSTRATIONS OF THE INFLUENCE OF FAT-SOLUBLE A AND WATER-SOLUBLE B ON THE GROWTH AND NUTRITION OF RATS

Here are given a number of curves illustrating the changes in body weight of rats which were fed from an early age upon an artificial ration of purified protein, carbohydrate, fat and inorganic salts, supplemented with adequate amounts of the factors "A" and "B." *

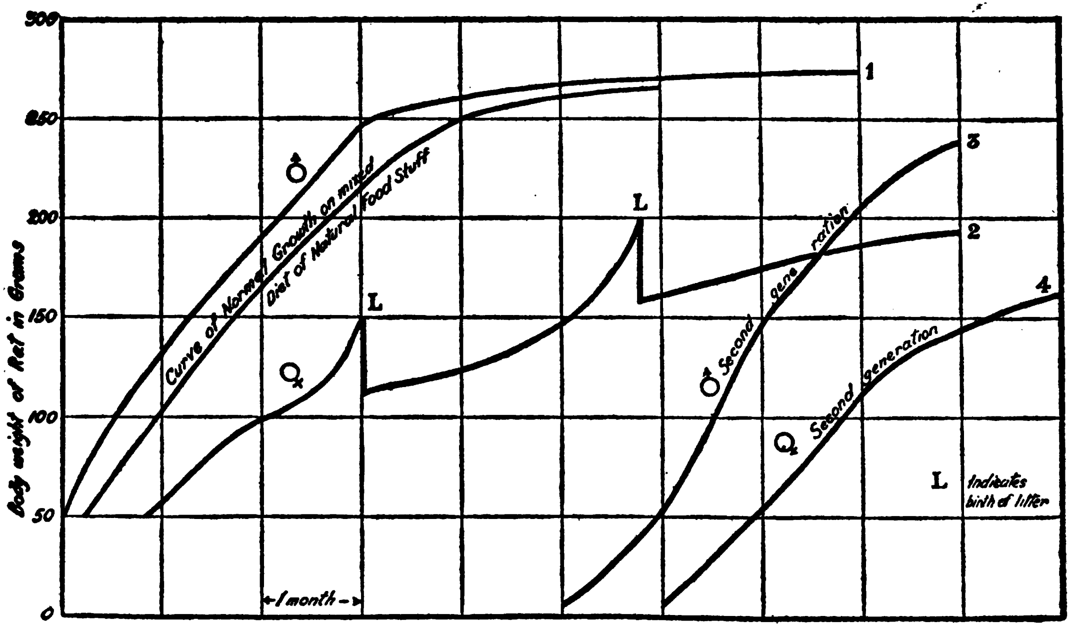
The actual dietary employed was constituted as follows: Purified casein, 20 parts; Purified starch, 55 parts; Mixture of crystalline inorganic salts, 5 parts; Butter fat (as source both of fat and the factor "A"), 15 parts; Yeast extract (as a source of factor "B"), 5 parts.

Chart shows normal growth of rats over 4–5 months with production, and satisfactory growth, of young on above dietary.

Curve 1 represents the growth of a male rat, and Curve 2 the growth of a female rat. At the points marked on the second curve litters of young were born. Average curves for the growth of the second generation reared on this diet are given in Curve 3 (males) and Curve 4 (females). In one experiment four generations were reared upon this dietary as a sole source of food, and in every case the animals were well up to, and in some cases were considerably superior to, the normal standard.

Report of the British Medical Research Committee, 1919.

* The curves illustrating this section are taken from records obtained during experiments carried out by Drummond. They confirm those previously obtained by McCollum and his co-workers.


Body weight of Rat in Grams
300
250
200
150
100
50
0
Curve of Normal Growth on mixed Diet of Natural Food Stuff
♂
♀
L
← 1 month →
♂ Second generation
♀ Second generation
1
2
3
4
L Indicates birth of litter

Notice, please, that we have not *isolated* our vitamines. We have not the least idea of what they look like and little idea of what they are. All that we can say is that certain foods contain them and others do not. Still better, that certain foods contain one or more factors essential to life and others do not. We are made aware of their presence by a process of elimination. If a diet is adequate when butter fat is included, and not adequate when butter fat gives place to lard, we look to the butter fat for the missing factor. If after having examined the butter, our chemistry still affords us no help in isolating the effective substance, if after having accounted for every known constituent in butter fat without being able to trace the effective substance to any one of the constituents, then we are led to the conclusion (from our feeding experiments) that something is there which chemical analysis has so far failed to detect. We cannot see it but its effects are obvious. The effects come within the range of our senses. We cannot see micro-organisms with the naked eye; we detect their presence by the use of the microscope. We cannot see atoms and the still smaller electrons; yet science has found a way of measuring them. And so we have not so far been able to isolate a vitamine; we have not as yet been able to look at one; but our science teaches us how to know when it is present or absent *by its effects on the living organism.*

An Adequate Diet. From what has been said we may now formulate our revised conception of an

adequate diet. "The diet must contain, in addition to the long recognized dietary factors—viz.: protein, a source of energy in the form of proteins, carbohydrates and fats; a suitable supply of certain inorganic salts *—two as yet unidentified substances. One of these is associated with certain fats (hence fat-soluble A), and is especially abundant in butter fat, egg yolk fats and the fats of the glandular organs such as the liver and the kidney, but is not found in any fats or oils of vegetable origin. The second substance or group of substances of chemically unidentified nature, is never associated with either fats or oils of animal or vegetable origin. It is widely distributed in natural foods, and can be isolated in a concentrated, but not in a pure form, from natural foodstuffs by extraction of the latter with either water (hence water-soluble B) or alcohol. This water or alcoholic extract always contains the substance which cures polyneurites [polyneurites in birds is comparable to beriberi in man. See the next chapter]. (McCollum.)

Objections to the Use of the Word "Vitamine." In the early part of this chapter we stated that objections were not wanting to the name *vitamine*.

* So as to satisfy the curiosity of some of my readers, I shall give the composition of a salt mixture that has proved to be extremely successful. I may add that much labor has been expended in the search for suitable salt mixtures. The composition is as follows (the numbers refer to grams): calcium carbonate 134.8; magnesium carbonate 24.2; sodium carbonate 34.2; potassium iodide 0.020; potassium carbonate 141.3; phosphoric acid 103.2; hydrochloric acid 53.4; manganese sulphate 0.079; sulphuric acid 9.2; citric acid 111.1; ferric citrate 6.34; sodium fluoride 0.248; potassium aluminum sulphate 0.0245.

Funk, who coined the word, did so to show its relation to a group of substances known to the chemist as *amines;* for at one time Funk's experiments led him to believe that these substances are of an amine nature. But never having isolated them, we have really no way of telling. That has led Professor Hopkins in England to suggest the term *accessory substance.* But Professor McCollum's nomenclature, fat-soluble A and water-soluble B, is usually preferred in scientific circles, because, without specifying the nature of the substance, they tell us that there are at least two such substances, and they also tell us something about their solubilities.

But really Hopkins and McCollum's objections are not very impressive. We still speak of *organic* chemistry, though we really mean the chemistry of the carbon compounds. The word *organic* came to be used at a time when compounds belonging to this branch of the science were supposed to have something *vital* in them. But when Wöhler disproved this theory chemists still clung to the name. The name had become established in the literature; and so long as we remember to attach no particular significance to the word itself but only to what it represents, we may with much convenience cling to the word organic. And so we do.

Funk coined the word *vitamine* before McCollum had shown that there were at least two such substances; and the world of science began to use the word accordingly. Why not allow the word *vitamine* to stand for a group of substances of which

fat-soluble A and water-soluble B are examples? We need no more think of vitamine as *amine* than we need think of organic chemistry as the chemistry of compounds contained in, or produced by, organs. But apart from all this, the word has already crept into the scientific literature. Even the public press is using it. The layman may be tempted to talk *vitamines,* but he will turn his back scornfully on fat-soluble A and water-soluble B, and perhaps, later on, on something C and another D and so on. We need do nothing further to discourage our lay public in their quest for scientific knowledge.

CHAPTER X

VITAMINES AND PLANT GROWTH

In the summer of 1912 the author well remembers how he and others were impressed with a remarkable lecture delivered by Professor Gabriel Bertrand, of the Sorbonne, Paris, on the effect upon the growth of plants of minute additions of one or two elements, particularly manganese. One part of manganese in one million of the culture solution appreciably increased the growth of molds. It was inevitable that such profound influences due to microscopic amounts of substances should give rise to much speculation. Scientists recalled such substances as adrenalin and iodine which are present in minute amounts in glands of the body, and which exert a profound influence upon our well-being. And above all, there are these enzymes, which forever synthesize and analyze materials in the plant and animal kingdom, and which also are present in such minute quantities.

Next came an unfolding of the entire field of vitamines, an account of which we have already given. Here again the effective quantities are ridiculously small. These little things that are brought with such difficulty within our sphere of

vision are equally important with the bigger things that our senses grasp much more easily.

Do Plants Need Vitamines? If animals need vitamines, do plants? And if so, where do the plants get them? We have already seen that our vegetable products may contain vitamine (see also the summary), but to what extent, if any, do they themselves need them? Or do the plants merely build these vitamines so as to supply us with a necessity?

Auximones. We owe whatever information we have on this subject to Professor Bottomley, an English botanist. He has shown that the prevalent idea that the plants merely need simple inorganic materials, such as carbon dioxide, water, and mineral salts in order to build up their organic structure, is erroneous. Working with several varieties of green plants, Professor Bottomley has been able to prove that "the addition to the inorganic nutrients of minimal quantities of certain organic substances is absolutely essential if the plants are to grow healthily and normally for any length of time." What was added was not really a pure organic substance, but a complex mixture; but the mixture contained an unidentified substance which had the power of maintaining life and stimulating growth in plants. This unidentified substance—or substances?—Professor Bottomley calls an auximone.

Auximones and Vitamines Are Probably Identical. Now the reader will need to use little of his imagination to see how readily this idea of

auximone in plants fits in with the vitamine hypothesis in animals. Professor Bottomley himself was the first to recognize that his auximones are similar in *function* to the vitamines, though not necessarily so in *nature*.

Where do these auximones, or vitamines, or growth-promoting substances in plants come from? They are organic in nature—presumably; that leads to the supposition that they are derived from the organic matter of the soil in which the plant is growing.

"Organic matter of the soil" is still rather vague. The soil is very complex and much of it is organic—a complex mixture of carbon compounds plus no end of bacteria. Here again Professor Bottomley, and Miss Mockeridge, his assistant, bring us enlightenment; for they have noticed that whenever peat is attacked by soil bacteria so that it decays, plant vitamines appear in much force. Such a decomposing peat can be shaken with water, and the watery extract can then be shown to stimulate plant growth and also to stimulate soil bacteria particularly the type that bring about the decomposition of peat. This has led to the suggestion that the plant vitamines—and in the ultimate analysis this would include the animal vitamines—are actually produced by soil organisms. In support of this contention Professor Bottomley has performed experiments which illustrate how, whenever the bacterial activity in the soil increases, we get a corresponding increase in vitamine activity. The organic manures usually applied in agriculture,

such as leaf mold and stable manure, were examined. They all contained varying proportions of water-soluble vitamine corresponding to the water-soluble B variety with which we are already familiar. But in every instance an extract of well-rotted manure, where bacteria are particularly abundant, was far more effective in bringing about growth in plants than an extract of fresh manure.

Just as with the vitamines the animal needs, the amount of plant vitamine that the plant needs is so small, that such an addition to the plant nutrients cannot materially add to their calorific value.*

* Mr. C. H. Richardson, of the Government Bureau in Washington, is engaged in experiments with insects which tend to show that vitamines are just as important to them as they are to us and to plants (private communication from the author); and we have good reasons for believing that yeasts and bacteria need these vitamines too.

CHAPTER XI

VITAMINES AND BERIBERI

Beriberi Symptoms. Beriberi is a disease which at one time was particularly common among oriental people, though by no means unknown outside of Asia. Its final stage takes the form of a general paralysis, which is usually very quickly followed by death; but it has a number of earlier symptoms that physicians have discovered. The first diagnosis may point to nothing more than a catarrh, but this is followed by pains in the limbs, by swelling of parts, by extreme weakness and possible paralysis of legs. If the disease makes further headway, the swellings will extend in size and increase in number; so will the paralysis; and with all this there develops a marked difficulty in breathing. In time the patient can neither walk nor move his arms, and his heart may become seriously affected.

Until quite recently the cause of this disease was a mystery. The popular belief was that it was due to an infection. Some physicians, however, insisted that its origin must be traced to a faulty diet.

Beriberi Among the Japanese. The "diet" the-

ory was very strongly advocated by Takaki, at one time medical inspector-general of the Japanese navy. He had made very extensive studies of European systems of hygiene, and found that in this respect Japanese sailors suffered little by comparison with European sailors. The latter had few or no beriberi cases, whereas the Japanese were simply infested with them. Clearly beriberi was due to something other than infection.

While in Europe Takaki had noted the proportions of fat, carbohydrate and protein that were distributed among the men. By comparison with the Japanese, the Europeans were getting far more protein. Much of the Japanese diet consisted of rice, which contains a high percentage of carbohydrate. Takaki therefore recommended that other foods richer in protein be substituted for part of this rice. Like all innovations, this one met with much opposition.

Then in the early eighties of the last century came the opportunity for a crucial test. A Japanese training ship, the *Ruijo,* with 276 men on board, set out for a cruise of nine months. During this time 169 cases of beriberi developed, and of these, 25 died. Soon after, another training ship, the *Tsukuba,* with a similar crew, was sent out over the same route; but this time, as the result of Takaki's earnest plea, the crew's diet was radically changed. The most marked departure in the diet was to reduce the quantity of rice and include a fairly liberal supply of milk and meat, the latter two yielding the increased amount of protein. The

change was nothing short of miraculous. During ten months only 14 cases of beriberi developed, and every one of these men had refused to adopt the modified diet!

Takaki became the hero. Rice, which the Japanese had eaten almost exclusively, was now reduced in quantity; meat, fish, vegetables and milk were substituted, and everywhere the beneficial results of the modified diet were in evidence.

You will remember that Takaki regarded beriberi as being due to protein deficiency, and the results apparently confirmed his view. We must now record some observations which will prove that the disease is not due to protein, but to vitamine deficiency; that rice of the type used by the Japanese is woefully deficient in vitamine of the water-soluble B type; and that the addition of meat and vegetables and milk supplied the necessary vitamine.

Polyneurites in Fowls. We must turn our attention to another eastern colony, Java, a Dutch settlement. The year is 1897. For fifteen years—ever since 1882—no further progress on the cause of beriberi had been made. Many had adopted Takaki's view of protein deficiency. Some still adhered to the infection theory. An accident led Eijkman, a Dutch physician stationed at Java, to re-investigate the whole subject. He had some fowls that were to be used for a number of experiments in which he was interested. One fine day all the fowls fell sick. The symptoms they developed were characteristic of the symptoms the

natives developed in beriberi, only to distinguish it from the form common to human beings, Eijkman called the disease in fowls *polyneuritis*. But how did the fowls get the disease?

Upon questioning the attendant, the important information was brought out that some days preceding the outbreak the fowls were fed with some cooked rice left over in the hospital kitchen. Eijkman thereupon replaced the diet of cooked rice with another also consisting of rice, but in the raw, unhusked condition. The fowls very quickly got well again.

"Polished" Rice. At this point it must be explained that in the original state the rice proper is surrounded by a skin, the pericarp, which may be white, or yellow, or red, or nearly black, or any combination of these colors. Outside the pericarp is the husk. The "polished" rice, white in color, results from a process of milling whereby the pericarp and the entire outer portions are removed. "Cured" rice still retains some pericarp, but no husk. In our description so far, wherever rice was stated to be the cause of beriberi, the reference was to the highly polished variety.*

The cooked rice that had been given the fowls was "polished" rice. Eijkman quickly followed up his preliminary investigation by showing that polished rice always induced polyneurites in birds, and that the addition of some unpolished rice, or merely its outer coating, which is discarded in

* The European and American diet is usually so varied that no amount of polished rice in our diet will induce beriberi. The case is often different with Orientals.

Eijkman's work was neglected, but investigators were independently arriving at Eijkman's results. Two Englishmen, Drs. Frazer and Stanton, in a survey of the Malay peninsula during 1908-1909, showed that the native laborers never suffered from beriberi if fed with "cured" rice, and that sufferers could always be restored to normal health if fed with "cured" or unhusked rice in the place of the polished variety.

In the Philippines. The following year, Major (now Colonel) Chamberlain, of the U. S. Army Medical Corps, and a number of his associates, working in the Philippines, reduced beriberi cases among the Philippine Scouts by changing their diet in much the way that Eijkman and Frazer and Stanton had done. Among the 5,000 men composing the Scouts, there were always from 100 to 600 laid up with beriberi. This state of affairs continued until 1910. In that year Major Chamberlain substituted unpolished rice and a small quantity of beans for the polished rice. The diet prior to 1910 had consisted of 12 ounces of beef, 8 ounces of white flour, 8 ounces of potatoes and 20 ounces of polished rice. The modified ration was the same except that in the place of 20 ounces of polished rice, 16 ounces of unpolished rice and 1.6 ounces of diet beans were provided.

The figures speak for themselves. At the end of 1910 the beriberi cases dropped to 50; the following year there were three; in 1912, two; in 1913, zero.

Yeast a Cure for Beriberi. Eijkman's pioneer researches and the whole subject of deficiency

diseases was brought to the front again by Casimir Funk's investigations during 1910-1912. Following up the Dutchman's observations on beriberi, Dr. Funk showed that an excellent source of the "something" which can cure beriberi is yeast. Yeast contains a "something" which apparently is identical with the "something" in the husk from rice. But Dr. Funk's plans were ambitious. He wanted to isolate this "something" from yeast. The operations he employed for doing this were elaborate and technical. Those who are interested may consult Funk's original papers, references to which are given in the bibliography. Suffice it to state here that starting with 200 pounds of yeast, he ended up with one-twelfth of an ounce of a substance which he called *vitamine* for reasons already explained in the last chapter, and which substance he considered was responsible for the cure in beriberi.

An Attempted Isolation of the Vitamine. While we cannot go into the laboratory details of this vitamine preparation, the method of procedure may be illustrated. You have your bird—Funk employed pigeons—and you feed it with polished rice. Beriberi develops; but since the bird is the hospital patient, we must call the disease polyneuritis. You next take a little bit of your ground yeast and mix it with the polished rice. The beriberi disappears. Yeast contains the curative agent, just as does the husk in rice. You next take your yeast and by a chemical reaction, or a series of such reactions, you get two fractions, A and B. You now

prepare two more patients by feeding pigeons with polished rice, thereby inducing polyneuritis. To the diet of one of these beriberi pigeons you add a little bit of A. The bird does not revive, but gets worse and worse and finally dies. To the diet of the other animal you add a portion of B; the bird completely recovers. From this it follows that of your two fractions, A and B, A does not, and B does contain the vitamine. Whereupon you discard A altogether and from now on confine your attention to B. You now proceed by another series of chemical reactions to divide B into two or more fractions, and you test each fraction for the vitamine by its effects when added to a diet of polished rice. This again leads to a rejection of one or more fractions; and once again you need confine your attention to only a part of the entire material. And so you go on. By this process of elimination Dr. Funk's 200 pounds of yeast yielded him one-twelfth of an ounce of very active material. So active was this material that an amount of it weighing no more than one fifteen-thousandth of an ounce, when added to an otherwise unsatisfactory diet, cured paralyzed pigeons within a few hours.

At one time Funk thought that his isolated product was 100 per cent pure; that the one-twelfth of an ounce was all vitamine; and that no impurities were present. But now neither he nor other workers in the field are very certain of its purity. There are good reasons for believing that even this small amount of vitamine isolated from 200 pounds

of yeast still contains substances other than vitamine. But Funk's work on the attempted isolation of the active substance did prove what a profound influence on life an incredibly small quantity of the substance exerts. One fifteen-thousandth of an ounce of vitamine product which, please remember, is still not pure vitamine, cannot add much to the energy value of the food; it certainly cannot add much to our stock of protein, carbohydrate, fat and mineral salts; yet its presence makes life possible and its absence makes life impossible. We are here dealing with a phenomenon which the layman finds as hard to grasp as the ether that is supposed to pervade all space; but the evidence in favor of a vitamine is more convincing than that in favor of an ether.

Let us hasten to add that no *known* substance which is 100 per cent pure will cure beriberi. Neither fat, protein, carbohydrate, mineral salts, nor any of the other countless products with which the chemist is familiar, will cure—always provided the substances used are *pure;* for remember that in the ordinary foods we eat, the vitamine is present among what we call the "impurities." *

Beriberi Vitamine and Water-Soluble B Vitamine Are Identical. The vitamine that cures beriberi is identical with water-soluble B vitamine.

* Dr. Williams, of the U. S. Department of Agriculture, performed a number of experiments which led him to believe that some compounds belonging to the chemical group known as purines do show vitamine properties. This has not yet been confirmed by other workers. Where in the one or two cases Dr. Williams' work has been repeated by others, they have failed to confirm his results. But perhaps it is a little too premature to pass judgment.

The evidence for this is as follows: All foods containing water-soluble B (see summary) have been used successfully to cure beriberi; all other foods are valueless for this purpose. Foods containing fat-soluble A only are valueless. For example, no amount of butter fat, rich in fat-soluble A, is of the least value as a cure. On the other hand, unpolished rice, or yeast, or beans or whole wheat are excellent restoratives. Of course one food may contain more of the water-soluble B than another; therefore the amounts to be used to relieve beriberi will vary with different foods.

This leads us to a very definite test for the presence of water-soluble B. Will a portion or an extract of your particular food cure beriberi (which, remember, you can readily induce in birds by feeding them with polished rice, or with any other food deficient in water-soluble B)? If it does, it contains water-soluble B; if it does not, water-soluble B is absent.

The discussion in the preceding, and in this chapter, and particularly the discussion of Dr. Funk's work, inevitably leads us to the conclusion that there is a something which is not any one of the recognized foods and which is present in foods in infinitesimal amounts, that is absolutely essential to all life. I say "all life" advisedly, for we have already seen how Professor Bottomley's experiments have proved that what is true of animals is also true of plants. This something Funk calls a vitamine. In the preceding chapter we have presented evidence to show that there are at least

two substances of this type, fat-soluble A and water-soluble B. We shall presently give reasons for believing that there are more than these two vitamines.

CHAPTER XII

VITAMINES AND RICKETS

Professor McCollum's researches, described in Chapter IX, have shown us that there are at least two distinct vitamines, fat-soluble A and water-soluble B. The latter is identical with the vitamine that cures beriberi. Since beriberi is a nerve disease, the water-soluble B that cures this disease is called the *antineuritic* vitamine.

Now the question arises, does the absence of fat-soluble A from the diet give rise to some specific disease? As early as 1913 Drs. Osborne and Mendel noticed that a deficiency of fat-soluble A in the diet of rats gives rise to a characteristic infection of the external eye, known as xerophthalmia. The progress of the disease is rapid, and if not checked, the cornea may become involved and total blindness may result. The frequency of this eye disease among rats whose diets did not include the fat-soluble A factor led Professor McCollum to the view that xerophthalmia is a direct consequence of the absence of this vitamine. This view, however, has not gone unchallenged.

Drs. Hopkins and Funk are of the opinion that

rickets is the result of fat-soluble A deficiency and English schools of physiology and medicine have supported them in this view. In America this opinion has met with some opposition. This opposition really resolves itself into something like this: we do not deny that fat-soluble A is one of the causes, but we do not think that it is the *only* factor involved.

Fat-Soluble A and Rickets. Fat-soluble A is one of the causes of what? Of rickets. Rickets is defined by Sir William Osler as "a disease of infants, characterized by impaired nutrition of the entire body and alterations in the growing bones." Perhaps no disease commoner to infants living in the temperate zone is known. Though particularly widely distributed among the poorer classes, it is by no means uncommon among children of the well-to-do. In America children of Italian and Negro parentage are great sufferers; 90 per cent of the infants in an orphan asylum in New York were found by Dr. Hess to be suffering from rickets in one form or another.

Dr. H. Gideon Wells, the eminent Chicago pathologist, who spent some time in Roumania on behalf of the American Red Cross, relates how many of the children were stricken with eye-disease, often a very characteristic symptom when fat-soluble A is absent from the diet. For a long time the diet of the poor little unfortunate ones had consisted of corn meal and a thin bran-vegetable soup, neither of which contains any fat-soluble A. Dr. Wells finally managed to procure some codliver oil

which, like butter fat, is rich in fat-soluble A. The eye disease disappeared soon after.

Anatomical Features. Glisson, an English anatomist of the seventeenth century, so accurately described the appearance of the body of a rickety child that a portion of his account may be reproduced: "The parts of the child are irregular and of unusual proportion. The head is larger than normal, and the face fatter in respect to the other parts. The external members and muscles of the body are seen to be delicate and emaciated. The whole skin, both the true and the fleshy and fatty layers, is flaccid and rather pendulous, like a loose glove, so that you think it could hold much more flesh. The joints are not firm or rigid. The chest externally is thin and much narrowed."

When a chemical analysis of rickety bones is made we always find the quantity of calcium to be unusually low. Calcium is the most characteristic element in the bone, and its low percentage in rickety children has led to the belief that an insufficient supply of calcium in the diet, or, more likely, a difficulty of utilizing the element, is an important factor in the development of the disease.

Symptoms. As for the symptoms, which usually appear before the child begins to walk, three stand out very markedly: first, an extreme sensitiveness to touch: handling the child will cause it to cry; secondly, a slight fever (100 to 102 degrees), accompanied by rather restless nights; and thirdly, profuse sweating. "The tissues become soft and

flabby; the skin pale; and from a healthy, plump condition, the child becomes puny and feeble."

Conflicting Views. In the past the treatment of rickets varied with the views held regarding its etiology. One school claimed that it could be traced to poor hygienic surroundings. Naturally, with such a belief in mind, the emphasis was placed on plenty of fresh air, on sunlight, on exercise. Another school claimed that it was due to a faulty diet; the fat in the food was insufficient. This gave rise to the use of codliver oil. This oil, belonging as it does to the class of compounds known as fats, is certainly rich in fat; but we now also know that it is rich in fat-soluble A. Perhaps the value of the oil is rather due to the vitamine it contains than to its content of fat? So thought Dr. Funk. So, also, thought Dr. Mellanby, an English observer. This investigator found that dogs deprived of fat-soluble A developed rickets. He showed that animal fats were *antirachitic*—that is, cured rickets, whereas vegetable fats did not. You will remember that Drs. McCollum, Osborne and Mendel had proved certain animal fats to be rich in fat-soluble A, whereas vegetable fats were poor in this vitamine, and that the animal fats were far better promoters of growth than the vegetable varieties.

Absence of Fat-Soluble A Vitamine Gives Rise to Rickets. Dr. Mellanby fed puppies with separated milk, wheat bread, linseed oil, yeast, orange or lemon juice and salt. They developed rickets

within six weeks. The diet was ample in calorific content. Its food constituents were well distributed. The yeast supplied water-soluble B as the antineuritic vitamine, and the orange juice, a vitamine preventing scurvy (see Chapter xiii). The linseed oil is a characteristic fat, but it is poor in fat-soluble A. As little as one-third of an ounce of butter or codliver oil completely prevented rickets. Remember that both of these are rich in fat-soluble A. Neither cottonseed, nor olive oil had any curative effect. "The above facts are in keeping with the idea that rickets is a disease primarily due to a deficiency of fat-soluble A vitamine. It is believed that the substances associated and contained with fat-soluble A are particularly concerned in the calcification process of bone and teeth" (that is in the utilization of calcium for the building of bone and teeth).

Let us hasten to add that Dr. Mellanby is a scientist of much distinction, and his opinions carry weight everywhere. During the war the British Government appointed a Medical Research Committee to investigate some of the pressing medical problems that arose as a result of the war. Among these problems was one dealing with infant diet, particularly the bearing of vitamine content in such diets. The Medical Research Committee in turn requested Professor Hopkins of Cambridge and Dr. Chick of the Lister Institute, to prepare a special report on the subject. If you turn back to page 91, you will recall this Professor Hopkins as the person who conducted a number of pioneer inves-

tigations on vitamines. During the last few years Miss Chick's researches on vitamines have won high praise on both sides of the Atlantic. After a very careful examination of Dr. Mellanby's work, both Professor Hopkins and Dr. Chick adopted Dr. Mellanby's view that the absence of fat-soluble A in the diet of infants, or its presence in insufficient amounts, is the primary cause of rickets. Professor Hopkins and Miss Chick drew up a report incorporating these views, and this report was adopted by the Medical Research Committee. The report was, and still is, very extensively used as a guide for those engaged in the administration of food relief in famine-stricken countries.

Further Confirmation of the View That Absence of Fat-Soluble A Vitamine Gives Rise to Rickets. Investigations by Japanese doctors have confirmed the views expressed by Dr. Funk and Dr. Mellanby. Among a group of children suffering from rickets, whose diet consisted of rice, barley, cereals, beans and other vegetables, a cure was very rapidly accomplished by the addition to such a diet of cod-liver oil, but not of olive oil. The former is rich in fat-soluble A; the latter is not.

Dr. Bloch had similar experiences in his clinic in Copenhagen. During the years 1912 to 1916, 49 cases of what was apparently rickets were very carefully examined by him. "The infants were pale, flabby and very thin, with dry, scaly and very shriveled skin. Of the 49 infants, 20 were between six and twelve months of age, 15 from two to six months, and 14 over one year. They would

scream and twist and turn, and wanted to be let alone. The malnutrition was extreme in many cases; for example, one baby of nine months weighed nine pounds, one of a year weighed 13½ pounds, another aged two years weighed 14 pounds. Their diet consisted of an indefinite amount of skimmed milk that had been pasteurized and cooked again in the home. Oatmeal-gruel and barley soup constituted an important part of their dietary. . . . A cure was obtained by means of codliver oil, though in almost every instance breast milk or raw cow's milk was also given."

Though what is now to be stated has been stated in a former chapter, I shall repeat it again, for it needs a number of repetitions: one vitamine factor in the absence of the other vitamine factor—or rather factors, as we shall see—does not cure. Where, as in the above examples, we speak of the fat-soluble A as being the curative agent, we imply that water-soluble B, etc., is also present; and vice versa.

And again I must emphasize that not all the vitamines in the wide world are of any use if the fuel needs of the body are not satisfied; or if there is not a well-balanced distribution of fat, protein, carbohydrate, etc.

Dr. Hess's Views. If I have referred to several investigators in European countries as favoring the view that rickets is a vitamine deficiency disease,—one due to the lack of fat-soluble A—I cannot overlook the work of a prominent American physician, Dr. Hess, which would tend to modify

such a conclusion. Dr. Hess reports a number of cases where children have had rickets even though their diet included an abundance of fat-soluble A. And on the other hand, he has noticed perfectly normal children whose diet included little or no fat-soluble A. Still he does not attempt to overthrow entirely the Funk-Mellanby theory of the causation of rickets, as the following extract from Dr. Hess's paper shows: "Our experience leads us to believe that except under exceptional circumstances—as in time of war—the danger to the infant and to the child from a deficiency of the fat-soluble factor is one not to cause great apprehension. It is true that this principle is by no means so widely distributed in nature as the water-soluble vitamine, but, on the other hand, infants seem able to thrive for long periods on very limited quantities, provided the diet is otherwise complete. The great danger arises from diets composed merely of cereal and water, or a perhaps insufficient amount of buttermilk or skimmed milk. It is probably true that a catastrophe will result if the incomplete diet is maintained for years, or even sooner in a susceptible individual, as is well known to be the case in scurvy and beriberi. In formulating dietaries for infants and children, therefore, this food factor should be borne in mind and be regarded as an essential constituent."

The last sentence is really the one that matters. Though by no means certain that fat-soluble A plays as important a part in rickets as water-soluble B does in beriberi, Dr. Hess does not advise

that the fat-soluble vitamine be discarded. In the preparation of diets for infants and diets for adults, the accumulated researches of many men in many countries deserve careful consideration. The consensus of opinion is that fat-soluble A is a vital factor in health, and that its absence in a diet is one of the causative factors in the development of rickets.

Distribution of Fat-Soluble A. Despite its name, fat-soluble A is by no means confined to those foods that are usually regarded as rich in fat. It is quite abundant in the vegetable world. Even the tomato, always considered one of the poorest of foods from the point of view of calorific value, is quite rich in fat-soluble vitamine, and incidentally in one or two other vitamines; so that the oft-heard cry that buying tomatoes means buying little more than so much water, is very far from the truth.

CHAPTER XIII

VITAMINES AND SCURVY

Scurvy is a disease that was common enough at one time among sailors, and often enough breaks out even to-day in famine-stricken districts. The symptoms may best be described by quoting Stefánson, the explorer. In speaking of several members of his arctic crew who contracted scurvy during 1916-1917, he says: "Anderson complained to me of having been gradually becoming more and more unwell for a week or two. The first symptom noted by him was dizziness on suddenly standing up, 'laziness,' gloom and irritability, showing itself in a tendency to condemnatory and uncalled-for argumentativeness, proneness to becoming tired, and loosening of the teeth and a swelling and recession of the gums, with a dull local ache in the gums or roots of the teeth. The appetite was normal both as to quality and kind of food desired. . . . Noice had become unable to walk and had to be hauled on the sleds; Knight was able to walk, but was getting weaker and more wretched. . . . At this time the teeth of the men were so loose that they could be plucked out with the fingers with no effort, and the gums were of such

a cheese-like consistency, that they were cut (with little bleeding) by wooden toothpicks about as easily as ordinary 'American' cheese could be. Every joint was sore and all movements painful. . . ." The spongy condition of the gums and the looseness of the teeth are often characteristic symptoms.

This disease, so common among sailors in days past that it was called the "calamity of sailors," is met with to-day only in famine-stricken countries, or among children living on a restricted diet. The devastation following the wake of the Great War has brought many cases of scurvy to the notice of medical men.

Scurvy a Disease Due to Vitamine Deficiency. Whatever doubt there may be regarding the relationship of vitamines to rickets, there is no doubt whatsoever that scurvy is a disease due to vitamine deficiency. Dr. Funk was among the first to advocate such a view, and subsequent work by many investigators has but strengthened it.

Water-Soluble C Vitamine. As we shall show, the vitamine, the absence of which gives rise to scurvy, is neither fat-soluble A nor water-soluble B. It is a third one of the substances belonging to the group of vitamines, which we shall call water-soluble C to distinguish it from the other two. Since water-soluble C cures scurvy, it is called the *antiscorbutic* vitamine, to distinguish it from the *antineuritic* vitamine which cures beriberi, and the *antirachitic* vitamine which is probably responsible for the cure of rickets.

For experimental purposes, guinea pigs are always used in work on scurvy. Rats cannot be used since, though they may suffer from a lack of vitamine C, they do not develop scurvy. You will remember that in studying beriberi, birds, particularly pigeons, were found useful. Rats can also be employed. Dogs can be used in experiments on rickets.

History of the Disease. The history of scurvy has elements of unusual interest. Chroniclers tell us how it attacked the Crusaders while in Palestine, and subsequent historians have seldom failed to record the ravages this disease wrought in the army of emperors. But one of the earliest detailed accounts of the disease, as well as an account of how to cure it, is to be found in the descriptions by Captain Cook, the famous voyager. Writing in the London *Philosophical Transactions* for 1776 on "The Method Taken for Preserving the Health of the Crew of His Majesty's Ship the 'Resolution' During Her Late Voyage Round the World," Captain Cook says: "We came to few places where either the art of man or nature did not afford some sort of refreshment or other, either of the animal or vegetable kind. It was my first care to procure what could be met with of either by every means in my power, and to oblige our people to make use thereof, both by my example and authority; but the benefits arising from such refreshments soon became so obvious, that I had little occasion to employ either the one or the other." This emphasis on *fresh* food strikes at the very heart of the matter.

Records compiled during the War of Independence for a period of 6½ years show that there had been some 30,000 cases of scurvy, about 400 of which ended fatally. The cases were very frequent where the ordinary rations were supplemented by dried vegetables. "At posts which could readily be supplied with potatoes only the taint was manifested."

In connection with the use of potatoes as an antiscorbutic, it is instructive to note that among the Irish peasants, where the potato is the main source of food, scurvy invariably makes its appearance after a potato famine.

In the recent war outbreaks of scurvy among the civil and military populations were quite frequent. In Italy and in Russia, and even in France, men and women and children became afflicted. Just at present Vienna presents a pitiable spectacle of the ravages of this disease. But scurvy is but one of several diseases from which the under-fed and badly-fed Viennese are suffering.

Infantile Scurvy. Not only may adults be attacked by scurvy, but so also may children. *Infantile scurvy* has been so exhaustively investigated by the English physician, Sir Thomas Barlow, that it is commonly known as "Barlow's disease." Much of Barlow's work was done in the early eighties of the last century. Apart from the knowledge we have since gleaned that the causative factor in scurvy is the absence of the antiscorbutic vitamine, Sir Thomas Barlow's description of the disease, as well as the cure for it which he sug-

gested, holds as good to-day as it did forty years ago. In one of his earliest papers Dr. Barlow points out that "prolonged deprivation of fresh vegetables or their equivalent is the most constant fact among the antecedents of the disease; and that uncooked meat and fresh milk are antiscorbutic just like fresh vegetables, though not to the same degree. The further we get from a living food the less is the antiscorbutic power. . . . I suppose it will ultimately be found that raw, uncooked milk is better than cooked milk." The last sentence is truly prophetic.

Dr. Barlow's Treatment. The cases of infantile scurvy that Sir Thomas Barlow describes are those of children who had never been breast-fed, but had received proprietary infant foods, condensed milk and perhaps a little fresh milk. Dr. Barlow's treatment consisted in giving each such child plenty of fresh milk—a full pint for a child six months old—sieved potato (in the place of the proprietary food), and a tablespoonful of orange juice. Striking recoveries were made in two to three days.

The treatment just outlined cannot be improved upon to-day. Sir Thomas Barlow's account of the disease, as well as his treatment of it, is a most complete clinical picture. What we do know today that Barlow did not know in the eighties, is that the foods that benefit the sufferer are rich in vitamine C.

Sir Thomas Barlow's opinion that the disease is intimately related to the type of food eaten has not gone unchallenged, despite the amazing results

which he obtained with his treatment of the disease. Russian physicians in particular were—and some still are—of the opinion that scurvy is the result of an infection. We have heard a similar story regarding rickets. It is so easy to regard each distinct disease as being due to a specific bacterium; and physicians, being mortal, and being impressed by the wonderful advances made by the science of bacteriology, are sometimes apt to lose all sense of perspective, and ascribe to bacteria the sum total of human suffering. But the fact remains that neither in rickets nor in scurvy has any microorganism in any way related to these diseases been isolated. Where infection has arisen it could be ascribed to secondary causes just as easily; to the generally lowered resistance of the body, for example.

Recently (March, 1920) Drs. Givens and Hoffmann, of the Western Pennsylvania Hospital, Pittsburgh, have presented the most convincing evidence yet advanced against the bacteriological hypothesis. Blood from scorbutic animals, regardless of the diet producing the disease, has been found to be sterile. "The enlarged front joints of guinea-pigs developing scurvy on oats alone were sterile; this was likewise true in the majority of cases of guinea-pigs developing scurvy on other special diets. Occasionally staphylococci were isolated, but these could not be made to produce scurvy when introduced into healthy guinea-pigs."

Equally unsatisfactory and vague is the hypothesis that the disease originates from some toxic

materials in the food. What these toxic materials are no one has the remotest idea.

The contention by Dr. McCollum that the curative value of antiscorbutic foods is merely due to their laxative properties, and that such foods are indeed interchangeable with such laxatives as liquid petrolatum and phenolphthalein, has been disproved, and I understand that Dr. McCollum himself no longer believes it. In his book on *The Newer Knowledge of Nutrition,* which was published in 1918, Professor McCollum says (page 97): "McCollum and Pitz found in the guinea-pigs which had died of scurvy, that the cecum, which is a very large and very delicate pouch through which the food must pass in going from the small to the large intestine, was always packed with putrefying feces. They decided that the mechanical difficulty which the animals have in the removal of feces of an unfavorable character from this part of the digestive tract was in some way related with the development of the disease.

"That this assumption was correct, was shown by the fact that the administration of liquid petrolatum, a 'mineral' product to which no food value can possibly be attributed, served to relieve a certain number of animals after they were near death from the disease, while confined strictly to the diet of oats and milk which caused them to develop scurvy. The explanation which they offered was that liquid petrolatum served to improve the physical properties of the contents of the packed cecum, and thus enable the animals to rid themselves of

this mass which was undergoing putrefactive decomposition."

As has already been stated, Dr. McCollum himself no longer shares these views. The criticism of his experiments centers around the quantity of milk he used. Milk itself contains water-soluble C, but not in very large quantity. If enough milk is given, or still better, if the milk is not heated under certain specified conditions whereby the water-soluble C is destroyed, the milk itself will act as a cure.

An Experiment to Show that Scurvy is a Disease Due to Lack of Water-Soluble C Vitamine. The postulate of vitamine deficiency fits the case of scurvy very well. Consider an experiment of this kind. You feed guinea-pigs* with a mixture of soy bean flour, whole milk, dried yeast, paper pulp and mineral salts. The guinea-pigs develop scurvy. You next add a little orange juice to the diet and scurvy rapidly disappears. The amount of orange juice added could have made no material difference in the calorific value of the food; nor could it have supplied any necessary amino-acid constituents. The flour and milk and yeast are rich in protein, fat and carbohydrate. The yeast supplies the water-soluble B or antineuritic factor; the milk, the fat-soluble A or antirachitic factor. Both of the two vitamines with which we have familiarized ourselves are present in the food supplied to the guinea-pigs. Evidently there is some other

* We owe to Axel Holst the discovery that the guinea-pig can develop scurvy.

factor necessary which only the addition of the orange juice to the diet supplies. This other factor, present in orange juice and in other fruits and vegetables, is the water-soluble C vitamine, or the antiscorbutic vitamine.

But you may say this still does not sound very convincing. Milk is the sole food of infants, yet according to your account milk contains no antiscorbutic. As a matter of fact, it does contain a little, but not enough; and where the quantity of milk is cut down to give place to other foods—as in the diet of the guinea-pigs just cited—the deficiency of water-soluble C becomes apparent. And indeed even where milk is the sole source of food, the tendency among physicians nowadays is to recommend the addition of orange juice two or three months after birth.

In this connection the clinical experiences of Drs. Hess and Fish are instructive. Early in 1914 an outbreak of infantile scurvy occurred in the Hebrew Orphan Asylum, New York. The infants afflicted had been fed for several months upon a diet of cow's milk which had previously been heated to 145 degrees (Fahrenheit) for 30 minutes. No orange juice was included in the diet, because two years earlier a Medical Milk Commission had declared that for purposes of infant feeding, heated milk was fully the equivalent of raw milk. Despite the conclusion of this Commission, Dr. Hess recommended the addition of orange juice to the diet. The scorbutic symptoms cleared up rapidly.

A diet even more frequently employed than the

above to produce scurvy in animals consists of oats, bran and milk that has been heated under carefully regulated conditions. Both fat-soluble A and water-soluble B are present in such a mixture, yet the animal develops scurvy.* Even large additions of butter fat or yeast to the diet has no effect whatsoever, showing that the scurvy is not due to a deficiency in fat-soluble A and water-soluble B vitamines. But the addition of a little orange juice immediately brings about a cure.

By developing scurvy in guinea-pigs and then trying the effect of the addition of various foodstuffs, we can determine which foods are antiscorbutic. In this way it has been shown that not only the orange, but all fruit juices contain the water-soluble C to a greater or less extent. So do fresh vegetables—cabbage, lettuce, potatoes, carrots and fresh meat. Milk, as we have stated, is not very rich in this vitamine; nor are dried vegetables. The cereal grains show almost an entire absence of it; so does heated or dried milk. The importance of adding orange juice to an infant's food consisting of dried milk now becomes evident.

Even where two or more vitamines are present in one food, the facts of the case are not as a rule altered. For example, experiments have shown that a diet in which clover or alfalfa is present to the extent of 5 per cent will supply the necessary

* "I regard the work of Givens and Cohen from my laboratory as most convincing because they used diets containing vitamine A, B, roughage, and good protein, and still secured scurvy." (Professor Mendel.)

quantity of fat-soluble A and induce growth in rats. If these vegetables are present to the extent of 15 per cent they will cure beriberi. The vegetables contain fat-soluble A and water-soluble B, but in different proportions. Orange juice, so valuable as an antiscorbutic, also contains appreciable quantities of the antineuritic vitamine that cures beriberi. The addition of orange juice to a child's diet, and its inclusion by the adult, serves, therefore, more than one purpose.

Dr. Seidell, of the U. S. Department of Hygiene, and Dr. Harden, of the Lister Institute, London, have shown how by the use of "Fuller's earth," a common laboratory chemical, and other substances closely related to it, the antineuritic vitamine in orange juice can be completely removed, leaving only the antiscorbutic.

Note how such an experiment can be carried out. Your orange juice in sufficient quantities cures scurvy and cures beriberi, which means that the orange contains both vitamines responsible for such cures. You now mix your orange juice with "Fuller's earth" and shake. You next withdraw the "Fuller's earth" and you find that it has acquired the property of curing beriberi, but not scurvy. Before mixing the orange juice with "Fuller's earth" the latter cured neither the one nor the other disease. "Fuller's earth," by being mixed with orange juice, must have *absorbed* the antineuritic vitamine. The solution that is left after the "Fuller's earth" has been removed has

the power of curing scurvy, but not beriberi. Hence we conclude that the antiscorbutic vitamine has not been removed by the chemical.

By the means outlined, any confusing results that might be obtained from the presence of more than one vitamine in the food is eliminated. For ordinary purposes, however, foods containing more than one vitamine are no drawback. We may certainly feel thankful that most of our foods do contain more than one vitamine.

Scurvy at the Siege of Kut. How specific in behavior these vitamines are may be illustrated in an account taken from the siege of Kut. For four months, from December, 1915 to April, 1916, British and Indian troops were besieged by the Turks. During this period the food of the Britishers consisted of white flour or biscuits, tinned meats and horse flesh. The Indians refused to eat fresh meat (horse flesh), but ate *ata* or barley flour instead. The Indians developed scurvy and the British beriberi. Why? The nature of the cereal diet (rich in water-soluble B) protected the Indian troops from beriberi, but not from scurvy. On the other hand, the fresh meat the British troops ate protected them from scurvy, for the meat contained water-soluble C, but there was nothing in their diet to supply the water-soluble B. The *white* flour and biscuits are practically free from water-soluble B.

Scurvy in Northern Russia. In the northern parts of Russia scurvy makes its appearance quite

regularly every year; yet the Allied troops sent to support the Anti-Bolsheviks were quite free from it. This was due to the fact that the British Government allowed itself to be guided, in its choice of food for soldiers, by the British leaders in nutrition. Professors Bayliss and Starling and Hopkins and Harden and Miss Chick have all been able exponents of the vitamine hypothesis. On their advice the Allied soldiers in Russia were allowed liberal amounts of such foods as soured milk, fresh meat, fresh lemon juice, etc. The results amply confirmed the claim made that scurvy is a deficiency disease due to the absence of one of the necessary vitamines.

Stefánson's Experiences in the Arctic. Stefánson's polar expedition, to which reference has already been made, has also presented striking evidence in favor of the vitamine hypothesis to explain scurvy. All foods rich in water-soluble C, all foods that cure scurvy in animals, proved excellent antiscorbutics when used on his arctic expedition. Stefánson's emphasis of *fresh* food also confirms the experiments of many investigators that desiccated or preserved or heated foods lose much of their potency.

The loss in antiscorbutic value of canned food was strikingly shown in some work by Miss Chick, of the Lister Institute, London. Heating cabbage or beans for one hour at a temperature close to that of boiling water decreased the anti-scorbutic value by 70 per cent; and canning involves such a

heating operation. Heated milk also loses its antiscorbutic quality. Even storage alone seems to have a deteriorating effect.

It should, however, be added that different antiscorbutic foods do show different heat-resisting power. The antiscorbutic in orange juice seems to resist increases of temperature much better than any of the antiscorbutics in other foods.

Stefánson's conclusions are worth quoting: "The strongest antiscorbutic qualities reside in certain fresh foods and diminish or disappear with storage by any of the common methods of preservation—canning, pickling, drying, etc. Fresh tomatoes may be of value—I have never tried them*—but canned tomatoes are of little or no value; fresh potatoes are good, but desiccated potatoes have shown little or no adequacy in our expedition. . . . The juice just expressed from fresh lime is said to be excellent, and I have no reason to doubt it; but bottled lime juice has never yet prevented scurvy. . . . Cooking lessens or destroys the value of most or all foods. . . . Bodily cleanliness and ventilation are not by any facts known to me shown to have any bearing on the incidence or severity of scurvy. Here it is instructive to compare the filth and good health of Nansen and Johansen, as described in *Farthest North,* with the immaculate Scott expeditions with their numerous and serious scurvy cases."

The last sentence is instructive, but it needs amplification to prevent it from being misleading.

* As a matter of fact they are.

Filth may bring on disease, *but that disease will not be scurvy.* The diseases due to filth are usually of bacteriological origin; but scurvy is not a disease due to bacteria; scurvy is not due to an infection.

The Value of Fruit and Vegetables. This and preceding chapters bring to light new values of fruits and vegetables. Aside from their agreeable taste and appetizing character, and aside altogether from their mineral content, which certainly should not be minimized, the fruits and vegetables supply very necessary constituents to the diet. The deleterious effect on the vitamine efficiency of canned and dried foods is unfortunate. Utilization to the maximum degree of our foods is imperative, and canning and drying help this considerably. The value of drying is still further enhanced by the way the weight and bulk of the material is lessened; in most cases the reduction may amount to from 50 to 90 per cent, a factor important enough in the matter of storage and transportation.

Canning and drying we must have, and canned and dried foods we must use. But until improved methods of preserving foods are invented, whereby the vitamine efficiency of such foods will not suffer diminution, we must supplement our diet with fresh fruit and fresh vegetables, and, in general, as many fresh foodstuffs as possible. In the meantime, the attempted preparation of stable vitamine products by Dr. Harden and others deserves much encouragement.

In this connection it may be mentioned that Miss Chick, of the Lister Institute, has found that

though dry beans contain little or no water-soluble C, these same beans, when allowed to sprout, do.* This discovery was used to advantage in the later stages of the Great War.

* This was first observed by Dr. Fürst in 1912.

CHAPTER XIV

VITAMINES AND PELLAGRA

We no longer have any doubt that beriberi and scurvy are diseases due to vitamine deficiency. We still have some doubts regarding rickets; but the doubt here is not so much whether rickets results from a deficiency of fat-soluble A, but rather to what extent is fat-soluble A necessary to prevent rickets? Even Dr. Hess, the opposition champion, does not deny that the presence of fat-soluble A in the diet is important; he simply questions whether this vitamine alone is sufficient to account for the disease; whether there are not other factors.

Pellagra is another one of those diseases that are due to nutritional deficiencies. As with rickets, we cannot as yet say very definitely that pellagra is due to the absence of one specific vitamine. The work of Dr. Goldberger, of the U. S. Public Health Service, points to a combination of causes, of which vitamine deficiency is one. The other causes may be due to deficiencies in the amino-acid content of the proteins, and deficiencies in the mineral salts.

Pellagra in the South. During the last twenty years the southern part of the United States has

had no less than 500,000 cases of pellagra, and ten per cent of these have ended fatally. It is a disease which at one time was regarded as being confined exclusively to the poorer classes, but now we know that even the well-to-do may be sufferers; for the disease is due to an *unbalanced* diet, not merely to a *poor* diet. Of course it is also true to say that the greater percentage of pellagra patients come from the poorer classes, for even the rich who are foolish indulge in a great variety of dishes, so that the possibility of vital deficiencies in any one necessary constituent are lessened.

Symptoms. The symptoms in pellagra may be described in the words of our best-known pellagra specialist in this country, Dr. Goldberger:

"In a fairly well-developed though not advanced case the disease shows itself by a variety of symptoms, of which weakness, nervousness, indigestion, and an eruption form the most distinctive combination.

"The eruption is the most characteristic telltale of the disease and the main reliance in recognition. When the eruption first shows itself it may look very much like a sunburn, the deceptive resemblance to which may, in some cases, be heightened by the subsequent peeling with or without the formation of blisters. In many cases the inflamed-looking skin first turns to a dirty brown, frequently parchment-like, then quickly becomes rough and scaly, or cracks and peels. In many instances the redness is not noticed or does not occur, the first and perhaps the only thing observed being the

dirty looking scaly patch of skin very much like and frequently thought to be no more than a simple weathering or chapping.

"Among the most distinctive peculiarities of the eruption is its preference for certain parts of the body surface. The backs of the hands in adults and the backs of the feet in children are its favorite sites. Other parts not infrequently attacked are the sides or front of the neck or both, the face, elbows, and knees. From these or other points, for it may attack any part of the body, it may spread to a varying degree. Another marked peculiarity of the eruption is its tendency to appear at about the same time, and to cover similar areas, both as to extent and peculiarities of outline, on both sides of the body. Thus it may be stated as the rule that if the back of one foot, one elbow, one knee, one side of the neck, one cheek, or the lid of one eye is affected, then the corresponding part on the other side of the body is affected, and affected to almost the same extent. This rule, however, is not without many exceptions."

Like the other diseases that we have discussed, pellagra has had its "infection theory" enthusiasts. There was some reason for such belief some ten years ago when it was noticed how rapidly it spread from place to place. But such a theory has now been thoroughly disproved. No pellagra germ has ever been isolated. All attempts to give persons pellagra by inoculating them with the blood or saliva of pellagra sufferers have failed. On the other hand, no difficulties whatsoever were en-

countered in curing patients by merely changing their diet, even though their surroundings were filthy in the extreme.

The Diet a Factor in Pellagra. Dr. Goldberger supplies us with several instructive examples. In an asylum which he investigated and which was surprisingly full of pellagra patients, the doctor noticed that the disease was confined to the inmates only; the doctors and nurses showed not a trace. Upon a careful investigation of the foods consumed, he found that the staff was abundantly supplied with meat and milk, whereas the inmates received but little of these precious foods. Dr. Goldberger thereupon added meat and milk to the diet of the inmates, and pellagra disappeared as if by magic.

Dr. Goldberger had similar experiences in three orphanages. In all of them pellagra made its appearance periodically, and many of the children suffered acutely from it. Here also the disease disappeared with the introduction of an improved menu.

And just as pellagra can be cured by changing the diet, so can it be deliberately induced by a one-sided diet. Eleven convicts who had volunteered for the experiment were given a diet consisting chiefly of biscuits, corn bread, grits, rice, gravy and syrup, with only a few vegetables and no milk, meat, or fruit. Six of the convicts developed pellagra.

Pellagra Outbreak in Egypt in 1918. All of these experiences in our own country merely typify experiences elsewhere. An instructive example was

the pellagra outbreak in Egypt in 1918. Thousands of Turkish and German prisoners were brought there and placed in concentration camps. Pellagra outbreaks were frequent and many, but the British doctors soon noticed that most of the pellagra sufferers were Turks; in fact, 90 per cent of the total were. Then the fact was brought out that for months past the Turks had received but two-thirds of their normal ration, which, even under the best of conditions, compared unfavorably with the rations allowed German or Allied soldiers. Their German general had reported that his Turkish soldiers were suffering from "long continued undernutrition." Increased food allowances, and more particularly, a more carefully balanced diet, soon improved the pellagra sufferers. And particularly instructive as throwing doubts on the infection theory was the observation how nearly immune to this disease were the German prisoners; and this, despite campaigning and living with the Turks.

Pellagra Studies by Officers of the U. S. Public Health Service. But if an improved, or still better, a well-balanced diet prevents pellagra, what factor or factors are of importance? We can answer this fairly accurately by examining the exhaustive report of the U. S. Public Health Service entitled, "A Study of the Diet of Non-Pellagrous and Pellagrous Households in Textile Mill Communities in South Carolina in 1916," the authors being Drs. Joseph Goldberger, G. A. Wheeler and Edgar Sydenstricker, Surgeon, Assistant Surgeon and Statistician, respectively, of the Service.

Seven villages in the northwestern part of South Carolina, each containing not more than 800 and not fewer than 500 inhabitants, were selected for study. Only white mill operators were considered; none of the families of mill officials, store managers and negro employees were included. A systematic search of pellagra cases was made from house to house. A careful survey of foods eaten by non-pellagrous and pellagrous households was made. This included a very elaborate social and economic program, for which Mr. Sydenstricker was particularly responsible. In all, the records of the food supply of 798 households, with an aggregate population of 4399 individuals, were obtained.

We shall now summarize the most characteristic portions of this report. One of its outstanding features was to show that protein consumed in non-pellagrous households included a greater proportion derived from animal foods, and a lesser proportion derived from cereals and, in general, vegetable foods, than in pellagrous families. We have but to return to the work of Professors Osborne and Mendel on amino-acids to draw the necessary inference. Proteins derived from vegetable sources are, on the whole, poorer in certain essential amino-acids than those derived from animal sources. The pellagrous households, therefore, have suffered from an insufficient supply of certain amino-acids. According to Professor Chittenden and Dr. Hindhede's standards, the protein requirements of the pellagrous part of the population were

more than met; the disease could hardly have been due to a mere deficiency of protein.

In the non-pellagrous households the consumption of lean meat, milk, butter, cheese and eggs was greater than in the households with pellagra sufferers. Notice in this list the foods man has relished for ages past. All of them are rich in proteins, which in turn are rich in the essential amino-acids. In proportion to the non-pellagrous households, the sufferers consumed but small quantities of milk; and this makes it probable that the quantity and variety of mineral constituents in the diet were deficient.

But of extreme interest to us is the fact that a decreased consumption of milk, meat, cheese and eggs means a decreased supply of the all-important vitamines; at least, a decreased supply of fat-soluble A and water-soluble B.

"The indications afforded by this study would seem very clearly to suggest that the pellagra-producing dietary fault is the result of some one, or, more probably, of a combination of two or more factors: 1. A physically defective protein supply—that is—a defective amino-acid supply; 2. A low or inadequate supply of fat-soluble vitamine; 3. A low or inadequate supply of water-soluble vitamine; 4. A defective mineral supply. . . . The pellagra producing dietary fault may be corrected and the disease prevented by including in the diet an adequate supply of the animal protein foods."

This disease, viz., pellagra, illustrates excellently

how, despite a sufficient number of calories, and despite a sufficient quantity of protein, the food may still be highly unsatisfactory.*

* At Yale University Professors Mendel and Underhill are now using the *dog* to study pellagra-like disease.

CHAPTER XV

SUMMARY. PRACTICAL APPLICATIONS

Instinct and experience combined guided us in our choice of food long before there was anything like a science of nutrition. The studies of our generation have confirmed what instinct and experience had taught us. But these studies have done more than that. They have in the first place supplied us with answers to the questions, why have we selected the substances we call food as material fit for body consumption? and why are some foods preferred to others? But aside from supplying us with a *raison d'être,* studies in the science of nutrition are helping to avert the food famine which in these days constantly hovers over us. In days past a comparative abundance of food supply enabled the individual to be prodigal with his produce. He ate much of many things. He ate more than he actually needed, and so assured himself a minimum quantity of certain essentials.

What these essentials were the man of the past did not know. Eating much, and eating a variety of things, he usually obtained the necessary elements in his food; but he also ate much that was not necessary. Or sometimes, despite abundance, he indulged in a one-sided diet, which led to many

diseases of which he and his offspring were victims. But to-day, with our limited food supply, we can no longer afford to be prodigal. Unless the essential factors in diet are known, and unless such knowledge is put into practice, we shall suffer from deficiency diseases even more than our forefathers. Fortunately, the science of nutrition has reached that stage where we can point out, with no little certainty, many if not all the essential factors in food. Such knowledge, combined with progress in the manufacture of artificial fertilizers, and in the manufacture by the chemist of artificial foods, will in time decrease the percentage of unfit among us. No longer will it be necessary to record that 20 per cent of our school children suffer from malnutrition, and that 25 per cent of the country's manhood are physically unfit.* And remember that these figures refer to the richest and most prosperous country in the world.

Calories. We have discussed the fuel needs of the body in terms of calories, the calorie being a unit used to measure heat; and we have seen that the adult needs from 2500 to 4500 calories per day, depending upon the type of work he does. Women need somewhat less, and the need of children is in proportion to their age.

Proteins, fats and carbohydrates. But we can-

* I, of course, do not overlook the fact that mothers are not always ignorant, nor are they always careless; and that a fair proportion of malnutrition cases is due to actual want in the family. The food expert can do little without the help of the social reformer.

not make the sweeping statement that any food which when taken in the body will burn to yield the necessary calories, is a satisfactory food; for a satisfactory diet means more than merely satisfying fuel needs. We need protein for the construction and repair of cellular tissue; and of the three classes of foodstuffs, protein alone answers this purpose. Not even fats and carbohydrates in quantities yielding 10,000 and 20,000 calories will serve as a substitute for the protein. Without protein life becomes impossible.

The fuel needs are supplied principally by the carbohydrates and fats.

Most of the foods we eat are mixtures of two or more of the three common classes of foodstuffs. Milk is one of the very few that contains all three. In a general way, meat is rich in protein; so is fish; whereas bread and the vegetable foods are rich in carbohydrate. Butter and animal fats, and animal and vegetable oils, are almost wholly fat.

Experience and scientific experiments have taught us the wisdom of carefully distributing our food among the three classes of foodstuffs. The standard diet for an adult suggested by Voit some 40 years ago still serves as the basis for our calculation to-day. The Voit diet consisted of protein 118 grams, fat 56 grams, and carbohydrate 500 grams. Or, in round numbers, protein 100, fat 50, and carbohydrate 500 (remembering 30 grams to be equal, approximately, to one ounce). Of late, the tendency has been to increase the fat somewhat.

The available statistics for Great Britain show-

ing the quantity of food consumed during 1909–1913 (in an average population of 45.2 million) are:

	Protein	Fat	Carbohydrate	Calories
Per head per day....	87	100	440	3090
Per man per day.....	113	130	571	4009

(The numbers refer to grams. "Per man per day" represents the average workman doing an average day's work; 100 of the total population—men, women and children—are reckoned as the equivalent of 77 men.)

For the composition of some of the common foods, see the Appendix.

"Ash" or mineral matter. In addition to the three classes of foodstuffs, the presence of "ash" or mineral matter in the diet is absolutely imperative. A diet of protein, fat and carbohydrate, in amount such as outlined above, and supplying even more than enough of fuel needs, will quickly cause death, unless mineral matter is also added to the diet. Fortunately for us, almost all of the foods we eat contain some mineral matter (see the table in the Appendix giving the composition of foods). The elements present in mineral matter are essential in the construction of protoplasm and bone, and in regulating the concentration of fluids in the body. Lime is needed for bone and teeth construction and repair; salt, for the formation of the juice in the stomach, iodine for the thyroid, etc.

Water, Oxygen, etc. Both water and oxygen are essential foods, for without either, life is impossible. The water is necessary for cell construction and

for the fluids of the body. The oxygen makes combustion possible; so that the foods, or their products, coming in contact with this element, are oxidized, and so liberate the heat necessary to propel the human engine.

The stimulants, condiments, etc., are of lesser importance. Their chief function is to "add spice to life"; they make life more agreeable.

Amino-Acids. Modern studies in nutrition have shown that not all proteins have the same value; which means that merely to talk of 118 grams of protein without specifying the *kind* of protein is of little consequence. The proteins have been shown to be complex substances composed of simpler units which the chemist calls amino-acids. All proteins when decomposed in a certain way yield these amino-acids (see Appendix). There are some 17 or 18—recently another one has been discovered—of these amino-acids, and all proteins are composed of the majority of these, but in varying proportions. Since what the body needs is not protein as such, but rather the amino-acids which go to make up the protein, modern nutrition stresses the need for satisfying amino-acid, rather than protein minimum.

And here again it has been shown that not all amino-acids are of equal physiological value. Some, such as tryptophane, are absolutely indispensable in a diet. Others, such as glycocoll, are not. Hence the importance of selecting those proteins which contain the necessary amino-acids.

Vitamines. But the most marked advance in modern nutrition is due to the proof that besides proteins, fats, carbohydrates and mineral salts, there are other as yet ill-defined substances which, though needed in but minute proportions, are yet essential to life. These substances are known as vitamines. At least three well-defined vitamines have been detected, which for purposes of identification we shall call fat-soluble A, water-soluble B and water-soluble C. The presence of all three of these vitamines is essential to well-being. As a matter of fact, very few foods contain all three. Milk is one of the rare exceptions, but even here the quantity of vitamine C that it contains is dangerously small. It is only by eating a variety of foods that we assure ourselves a liberal allowance of all three types of vitamine.

Fat-soluble A. This is present in abundance in milk and in butter and in egg yolk, and, to a lesser extent, in beef fat and in many vegetable foods (lettuce, spinach, cabbage, carrots, potatoes, etc.). Lard and vegetable oils, such as olive oil, are devoid of it. Cereals in general (wheat, rye, barley, etc.) contain little. In a general way the statement may be made that this vitamine is present in green leaves and in the embryos of many seeds.

Water-soluble B. This is more abundant than either of the other two. In fact, nearly all natural foods contain some of it. Yeast is particularly rich in this vitamine. So are milk and orange juice. The cereals contain it but only the outer

layers; so that in patent flour vitamine B is absent, but in whole wheat flour it is present.*

Water-soluble C. Most *fresh* fruit and *fresh* vegetables contain this vitamine. The emphasis is advisedly put on fresh material. The orange and the tomato are particularly good examples.

Effect of heat. All three vitamines are more or less susceptible to heat, so that any process involving this operation—cooking or canning—is apt to destroy, or greatly lessen, the efficacy of the vitamine. Of the three, water-soluble C seems most susceptive and water-soluble B least. One of the problems of the immediate future is to devise methods of drying, preserving and canning food, without at the same time lessening the vitamine value of such foods.

The function of the vitamines. If carbohydrates supply energy, and proteins, material for tissue repair, what does the vitamine supply? We really cannot answer this question very satisfactorily. Some liken vitamines to enzymes as being in the nature of catalysts. By a catalyst we mean a substance which influences chemical reactions without itself undergoing any ultimate change.

* Dr. Williams has devised a very delicate test for this vitamine. It depends upon the fact that yeast cells cannot grow and multiply unless water-soluble B is present. The procedure is to take single yeast cells and mix them with drops of different solutions that are under examination. If the solution contains water-soluble B the yeast cell will grow; and indeed the extent of growth gives us an idea of the *amount* of vitamine in solution. All this can be examined under the microscope. Where the water-soluble B is absent, no growth occurs. Dr. Williams' work, however, needs further confirmation.

Others are of the opinion that they are of the nature of hormones,—the active substances present in the various internal secretions (such as those in the thyroid and the adrenals)—in that they probably stimulate activity in the cells. Still others consider that their function is to supply certain chemical groups to the body which are quite essential, and which the body itself cannot manufacture.

In connection with these speculations, Dr. Steenbock has made the interesting observation that one of these vitamines—fat-soluble A—is always associated with a yellow pigment. Butter, egg yolk and codliver oil are all highly colored with this pigment. Colored roots such as carrots and sweet potatoes contain it, but sugar beets and Irish potatoes have little or none. These observations lead Dr. Steenbock to conclude that the yellow pigment and the fat-soluble A are very closely related. This view, however, has met with very much opposition.

Diseases due to lack of vitamines in the diet. At least two common diseases have been definitely identified with vitamine deficiency. One of them is beriberi, involving a general paralysis of the system, and due to lack of water-soluble B; and the other is scurvy, involving choppy gums and loose teeth, and due to lack of water-soluble C. We have reasons for believing that rickets, an infant disease, where the bones are underdeveloped, is due to deficiency of fat-soluble A, though so far

the experiments do not seem as convincing as in the other two cases cited.

The work of Dr. Goldberger, of the U. S. Public Health Service, has clearly demonstrated that pellagra, a disease frequently met with in the South, is a deficiency disease. The absence of vitamines A and B, or rather their presence in the diet in insufficient amounts, has much to do with the onset of this disease, though Dr. Goldberger believes that deficiencies in the diet of amino-acids and mineral salts are also contributing factors. Whether pellagra, one of the symptoms of which is a skin eruption, is due to lack of vitamines A and B, or to a lack of vitamines, certain amino-acids and certain mineral salts, or perhaps to a fourth as yet unidentified vitamine, is a subject for further study. That the absence of some one or several vitamines is a contributing factor is now generally conceded.

The vitamine that cures beriberi is called the antineuritic vitamine; that which cures rickets is the antirachitic vitamine; and the one which cures scurvy is the antiscorbutic vitamine.

A wholesome diet. We shall attempt to give no 101 recipes, but to draw a few general inferences from our discussion. In planning our diet we ought, wherever possible, plan it around *milk* as the nucleus. Milk, as we have seen, contains the three classes of foodstuffs, the mineral salts, proteins rich in the necessary amino-acids and all three vitamines. To be sure, it is somewhat defi-

cient in the antiscorbutic vitamine, which is the reason why physicians supplement the baby's milk diet with orange juice. But all in all, it is nature's food *par excellence*. Professor McCollum rightly considers milk as a "protective" food, in the sense that any deficiencies in the various foods eaten are well counterbalanced by a milk diet.

With this in mind, liberal quantities of milk or its equivalent (in the shape of cocoa or coffee) should form part of the daily diet. Realizing how sensitive to changes of temperature the vitamines are—and in this respect it should also be kept in mind that the milk proteins themselves undergo changes on heating which are still little understood—the milk, whenever possible, should be taken in a fresh, unheated condition. Neither pasteurized, nor condensed, nor powdered milk is fully the equivalent of the fresh milk.

With milk as the nucleus of the diet, we can now fill in the outer portions of the cell. A certain amount of vegetables and fruits should always be included—the particular kind depending upon the season.

Do not misunderstand any suggestion about freshness. I do not mean to imply that cooked or canned fruit and vegetables, or dried milk, is not valuable, or that they should be discarded. On the contrary, modern civilization could hardly exist without them. But if you do use the canned, etc., foods, remember that these cannot contain as much vitamines as the fresh varieties; so be sure to take a little "something fresh" every day.

Aside from their vitamine content—thereby supplementing the supply in milk—fruits and vegetables contain appreciable quantities of mineral matter, and are helpful as laxatives; and vegetables also contain carbohydrates.

With milk as the nucleus of the diet, and moderate quantities of fruit and vegetables added to the milk, we may still be somewhat deficient in protein requirements. These may be obtained from any one of the cereals, such as wheat, rye, barley, etc. The cereals are also rich in carbohydrate, though poor in fat.

Milk, cereal, fruit and vegetables can constitute a *complete* diet, provided, of course, we take enough to assure all calorific requirements. The milk and cereal supply the protein, and however deficient in certain essential amino-acids the cereal proteins may be such deficiencies are more than counterbalanced by the milk proteins. The milk, cereal and vegetables supply the carbohydrates; so does fruit, but to a less degree; and the milk supplies the fat. The amount of fat included in such a diet may not be very much, but it is still a question whether fat is really an essential constituent, provided always that the individual consumes enough carbohydrate. In any case the amount we usually consume is far more than we need. In America and England, particularly, where we cannot be tempted to eat bread without butter, the fat consumption is abnormally high.

All four food products, milk, cereal, fruit and vegetables, contain mineral salts, and they all con-

tain one or more of the three vitamines so far identified.

But you will say that this diet of mine does not include the most prized of foods, meat. We, and particularly we Americans, eat meat altogether beyond all requirements. With the diet just outlined we could live quite happily without ever tasting any meat. But I recognize that while hunger may be a purely physiological manifestation, appetite is more complex; and our highly-civilized man needs tempting dishes to make him enjoy his food. Perhaps the most tempting of all dishes is meat in one of its several forms. The roast chicken, the porterhouse steak, the lamb chops, etc., "make the mouth water"; and "making the mouth water" causes an abundant flow of digestive juices; and these digestive juices are necessary to prepare the food for assimilation.

So eat meat. Your meat will give you a food rich in protein and will stimulate your appetite. But with appreciable quantities of milk and cereal, fruit and vegetables, hardly more than two ounces, and certainly never more than a quarter of a pound of meat per day should be consumed.*

Fish plays much the part that meat does; both are valuable sources of protein, and, to some extent, fat; and whenever the milk and cereal consumed are not sufficient to supply protein needs—which will happen whenever such supplies are

* "Meat supplements the ordinary cereals and leguminous proteins to make the mixture better. Meat extract is one of the most potent gastric succagogues." (Professor Mendel.)

scarce, or perhaps too costly, or when one or both of them are disliked—meat and fish are invaluable substitutes.

Better even than meat and fish as an additional source of protein are eggs; for these are also rich in fats and particularly the fat-like substances, the lipoids, the importance of which to the body is only now beginning to be appreciated. For the growing child, for the nursing mother, for the convalescent, few foods are as nutritious, weight for weight, as are eggs.

The nursing mother. To emphasize not merely a plentiful, but a carefully selected diet for the nursing mother seems almost superfluous. The healthy mother has not only an abundant supply of milk, but a milk of good quality; and such milk for the child no artificial food can replace.

While, of course, there are a number of factors that have an important bearing on the health of the mother, the food factor, taken all in all, is perhaps the most important, and the one most often neglected. Here again the mother's diet should include a plentiful supply of milk—two and three times the quantity that she might ordinarily take—perhaps a quart or so a day. Since milk contains much fluid in proportion to its solid content, a good supplementary diet is the egg. A quart of milk and two or three eggs per day should constitute the principal item in the mother's bill of fare. But with these should come vegetables and fruit in moderation. Meat should certainly not be over-

emphasized. Take a little if you like it very much, but only a little.

The infant. You hear so often the remark, "Nothing like a breast-fed baby." This needs some qualification. Unless the mother's milk is excellent in quality, the breast-fed baby may suffer far more than the artificially fed one. But when the mother is in good health, and her milk is therefore of good quality, modern science merely confirms what untold years of experience have taught us: breast milk is superior to all other milk.

Breast milk. Having been taught that milk, irrespective whether human or cow's, etc., contains the three classes of foodstuffs, the mineral salts, the essential amino-acids and the vitamines, the reader may very naturally ask why breast milk for the infant should be superior to cow's milk? Of course the first answer that comes to mind is that the proportions of constituents in breast and cow's milk are different. Cow's milk contains more protein than mother's milk; the latter, on the other hand, contains more milk sugar. It is indeed customary, whenever the infant is fed on cow's milk, to dilute it and add some milk sugar. In this way you make the proportions of constituents in your modified cow's milk as nearly like to what it is in the mother's milk. But even when that is done there is quite a decided difference. So far as the chemist and the physician can tell, you have the same protein, fat, carbohydrate, mineral salts and vitamines in both kinds of milk. Just what is the

difference? We must confess that we do not know. Some physiologists claim that the proteins in the two milks are not quite the same; careful chemical analyses do reveal differences. Perhaps the protein has something to do with it.

Artificial feeding. Of course, where breast feeding is impossible, or possible but disadvantageous to the child, artificial feeding has to be resorted to. Modern pediatricians no longer do what their predecessors did; they do not risk their reputation on calories alone; nor merely on the proportion of the three foodstuffs to one another. They take into consideration all the various factors that the science of nutrition has taught them to be important; many of these have been discussed in this book.

"Modified," dried and condensed milk. Even where the infant is deprived of mother's milk, we have every reason to believe that ordinary milk—provided it is not diluted or treated in some special way—contains the three vitamines in sufficient quantity. Where, however, the child receives "modified" milk in one form or another, there it becomes most important to carefully examine such a product for its vitamine content. Codliver oil is a good source of fat-soluble A, and orange juice of water-soluble C.

Should the child receive dried or condensed milk, we must remember that the method of preparation of such milk probably destroys its content of water-soluble C, though we have reasons to believe that the two other vitamines remain fairly active. "In

the present state of our knowledge it is our duty to give our infants the best possible chance, and the wise course is to omit no precaution that may ultimately prove to have been necessary. An additional antiscorbutic should therefore be given to infants who are reared on any artificial food other than raw cow's milk. Even in this case, and that of the breast-fed infants, such a course might also prove beneficial." (British Medical Report.)

"*The Value of Milk for the Child.* Milk is absolutely essential for the life of infants and very young children.

"It is a most desirable adjunct to the diet of older, rapidly growing children.

"It is the main dietary reliance in cases of disordered digestion or extreme illness.

"Milk contains an abundance of protein, fat, carbohydrate and mineral nutrients, and its proteins are not only of superior value when used alone, but they are especially adapted to supplement the protein deficiencies of the cereals which form so large a part of the daily ration of mankind. Its mineral nutrients also supplement the deficiencies of the cereals, meat, sugar and fats in these important elements. Moreover it contains the three vitamines without which life cannot be maintained.

"The scurvy-preventing vitamine is destroyed by heat, and therefore if infants are fed on pasteurized or sterilized milk the use of orange juice or some vegetable extract is necessary to avoid the possibility of scurvy.

"Whole milk contains enough water-soluble vitamine to meet an infant's requirements, but if 'the top of the bottle' diluted with water is fed, the supply of this essential vitamine may be insufficient unless it is supplemented from some other source.

"Milk is the only food known which is capable of serving as the sole constituent of an adequate ration.

"Milk is a cheaper form of food at 16 cents a quart than either beef at 35 cents a pound or eggs at 35 cents a dozen." (Miss E. L. Ferry.)

Vegetarianism. The vegetarians who eat milk and eggs are not vegetarians, strictly speaking. No diet including milk and eggs is a deficient diet, provided always that enough of them is taken. Meat and fish need never be eaten and perfect health may still be maintained.

But the problem is a difficult one with the true vegetarian who would eat neither milk nor eggs. From what has already been said, we must consider milk as the most important of our foods. It is the protective food which makes up for various deficiencies in other foods. To make up such deficiencies without the use of milk, particularly where meat and fish are also excluded, is not only difficult but dangerous. Theoretically, there is no reason why a complete diet cannot be formed from a mixture of cereals, vegetables and fruit. If chemical and physiological analysis had proceeded far enough, we might have been able to select all the necessities from even such a restricted diet.

But though we know much more to-day than we did a generation ago, the science of nutrition is still far from complete.

Bread. Next to milk perhaps the commonest of our foodstuffs is bread. As already stated in a discussion on cereals, bread is rich in carbohydrates and contains moderate quantities of proteins (see Appendix). The proteins are rather poor in certain essential amino-acids. The amount of fat-soluble A present is small.

Bread is made from different grains. The most prized is that made from wheat. Next in public estimation comes rye, then barley, then oats, then maize. In so far as their nutritive content is concerned, there is little to choose between the various grains. If wheat is preferred to oats, the reason is not because the one contains more protein or carbohydrate, or because the one contains a protein of better quality; it is because the dough formed with wheat, and the bread ultimately produced from it, are more consistent; the wheat bread holds together better and is less granular than the bread made from oats.

Professor Sherman of Columbia, who has carefully investigated the nutritive values of the different cereals, arrives at the conclusion that no choice can be made among them. All are about equally efficient—or rather deficient; for a deficiency of a number of essential amino-acids in their proteins makes it necessary to supplement a cereal

food with other food. An excellent supplementary food for such a purpose is milk.

Much of the cereal eaten in this country and in Europe is eaten in the form of bread. The Orientals prefer theirs in the form of rice and corn, and these are usually boiled. The polished rice, without the surrounding layers that are found in the unpolished variety, has given rise to many cases of beriberi among Chinese, Japanese, Filipinos, etc. Had our Oriental friends eaten their polished rice together with other and various foods, beriberi would never have attacked them, for the deficiency in water-soluble B vitamine in polished rice might have been obtained from milk or vegetables.

Meat. Where dairy products are plentiful—where milk and butter and cheese abound—meat is of little importance. This has already been discussed. The amount of meat consumed is unnecessarily high in many cases.

Fruit and vegetables. The value of these foods has already been pointed out. In this country we derive about 15 per cent of our total calorific value of the food from fruit and vegetables. This could safely be higher. In comparison with other countries, we consume large quantities of beans and green peas, but rather small quantities of potatoes, cabbage, beets and turnips. The potato particularly is not used nearly to the extent it should. Professors Kellog and Taylor, at one time con-

nected with the United States Food Administration, inform us that in Germany before the war the annual yield of potatoes amounted to 45 million tons, whereas in the United States it was 9 millions. And think of the smaller population of Germany, and think of how much smaller their country is.

Our professors have calculated that in a mixed diet, five parts of the potato correspond to one part of grain. The potato is fairly rich in vitamines B and C, in mineral matter, in starch,—an easily digestible carbohydrate—and though less rich in proteins, these are fairly well balanced.

Our consumption of leaf vegetables, such as cabbage, spinach, Brussels sprouts, and root vegetables, such as beets, turnips and carrots, may well be increased. "The green vegetables supply an important addition to the diet of man because the staples, such as cereals, meat, potatoes, fats and sugar, probably furnish too small an amount of vitamines to meet fully the requirements of an adequate diet. Therefore care should be taken not to reduce greatly the quantity of green vegetables customarily eaten until more is learnt about the actual requirements for these food factors and their relative abundance in the commonly used vegetables and green foods. Only then will it be safe to apply the results obtained in the laboratory to attempts to effect economies in the use of these relatively expensive food products."

In the Allied armies the following vegetable ration was found to be satisfactory: potato 40

parts; carrots 20 parts; turnips 20 parts; cabbage 10 parts; onions 10 parts.

Fish. Though poor in vitamine content, fish is rich in protein and fat, and in that respect compares favorably with meat.

Sugar. This carbohydrate may be put to several uses. Its commonest use is as a sweetener, whether added to coffee and tea, or to candy. Most of us crave for sugar; the sweet we prefer to the bitter. There is an important psychological factor here that cannot be overlooked, for sugar in moderate quantities stimulates the appetite of most of us. But sugar is really more than a flavoring material; it is a very good food. The cane sugar that we use, and even the cheaper glucose that finds its way into confectioneries of various kinds, is very nearly 100 per cent carbohydrate.

As a conserver of fruits and in cooking of foods, sugar also finds constant use.

Table beverages. Tea, coffee, cocoa, chocolate and the now forbidden alcohol in its various guises, are not as a rule taken to increase the nutrient value of our foods. They act as stimulants. Here again the psychological factor comes into play. Of course a cup of chocolate which, let us say, consists of three-quarters milk or one-half cream and two or three pieces of sugar, is a very nutritious drink; but remember that the nutritive value is not de-

rived from the chocolate, but from the milk or cream and the sugar. For those disliking milk, an excellent method is to add a few teaspoonsful of coffee or cocoa to it, together with perhaps a little bit of sugar.

Fashion in foods. We must be careful in advocating certain diets to remember that man is not altogether a machine. The results of experiments in physiology and chemistry cannot always be applied in their entirety. You may discover from such experiments that milk is the most important of foods; yet the fact remains that there are people who dislike it, and who, therefore, because of such dislike, do not derive as much benefit from drinking milk as others who have no such dislike. I know (and you know) persons who dislike butter; others who dislike vegetables prepared in a certain way—they may like fried, but not mashed potatoes. Some like pot roast and others hate the sight of it. Some relish cheese full of odors, and others are ready to vomit at the mere mention of the name. And then you have variations in taste due to differences of religion, of race, of country. Watch the orthodox Jew make faces when he sees ham or pork. Watch the uninitiated American observe caution when he first attacks chop suey. Watch the Englishman throw up his hands in holy horror when his Spanish friends swallow garlic and onions.

David Fairchild asks the following interesting question: "How did seaweeds and candied grasshoppers come into use in Japan, and fried rhinoc-

eros' hide in Africa, and powdered deer horns in China, and pickled pigs' feet in Germany, and moldy cheese with skippers in it in England, and snails and frogs' legs in France, and grasshoppers, fried and reduced to a meal, in Arabia, and snakes and lizards among the North American Indians, and octopus among the Neapolitans, and wood-grubs among the New Zealand Maoris, and caviar, the eggs of the Volga sturgeon, among the Russians, and rats and mice and dogs and cats among the Chinese, and human flesh among the Fiji Islanders? . . . Is it not highly probable that these foods came into vogue just as we know coffee and tea and the potato and tobacco and chocolate have come to be fashionable to-day in European and American countries, through the encouragement given by those who set the fashion of the day?"

The Future. The solution of the food problem does not rest merely with the physiologists and clinicians, who sort out the foods and tell us that one food is more wholesome than another. This is important enough, but it is not embracive enough. For to-day the question is not merely one of selecting, but of procuring foods. Side by side with researches on the biological and chemical value of foodstuffs, other researches closely bound up with these must be carried on. Means for more intensive cultivation of land, which includes the improved manufacture of artificial fertilizers, are well under way. But the chemist must also find ways of manufacturing foods from substances not

foods. I have in mind such a problem as the production of glucose from formaldehyde ("formalin"), and of converting complex, indigestible material into digestible food. A successful illustration of the latter is the conversion of cellulose—the typical carbohydrate that covers plant cells—into glucose by heating with oil of vitriol. Still another way of attacking the food problem is by utilizing little known foods. For example, how many of us use soy beans, cultivated so extensively in Japan? You may be surprised to hear that this variety of bean contains twice as much protein and fat as meat. Dr. Rogers' advocacy of the usefulness and the palatibility of shark meat is another instance of the attempted introduction of little known foods.

I can think of still another method to which bacteriologists have already paid some attention. The lower plants, such as yeast, can use as food, compounds that man cannot use. By so doing, these yeast plants build protein, fat and carbohydrate material—in the shape of more yeast cells. In other words, the yeast cells multiply on a diet which we could not make use of at all. To make this a little more specific: ammonia may be obtained in two ways, either from coal, or by directly combining the elements nitrogen and hydrogen (Haber process). Ammonia in the form of one of its salts is a good source of nitrogen food for yeast, whereas the only nitrogen food we can use is protein, or the amino-acids out of which the protein is built. The yeast will use these ammonium salts,

and out of them it will build proteins, which we can then use as a source of protein food. So you see that, traveling by an indirect route, we may be able to get protein from coal; or still better, starting with the nitrogen of the air, and the hydrogen which can be obtained by electrolyzing water, we may ultimately reach the protein stage. Romantic enough, is it not?—to dream of supplying protein needs from the air and from water? Yet this romance has much of fact mixed with it.

APPENDIX

TABLE OF COMPOSITION AND CALORIE VALUE OF THE MORE IMPORTANT FOODS ADOPTED BY THE INTER-ALLIED SCIENTIFIC FOOD COMMISSION

Commodity.	Protein. %	Fat. %	Energy value per kilo. Calories.
Cereals—			
Wheat and barley flour	11.5	1.0	3,640
Oatmeal	16.0	8.0	4,000
Barley meal	10.5	2.2	3,600
Tapioca, sago, arrowroot, etc	8.3	0.6	3,650
Maize meal	7.5	4.2	3,500
Rice	8.0	0.3	3,540
Meat—			
Beef	15.0	18.0	2,290
Veal	16.0	6.3	1,230
Mutton	13.5	24.0	2,790
Lamb	15.0	18.9	2,370
Bacon	9.5	60.0	6,000
Ham	14.5	34.0	3,750
Other pig meat (fresh pork)	10.0	40.0	4,120
Meat offals	20.0	10.0	1,750
Poultry, Eggs, etc.—			
Poultry (and Game)	15.0	9.5	1,500
Eggs (at 2 oz.)	12.0	9.5	1,400
Rabbits, imported (excluding skins)	21.7	10.8	1,900
Fish—			
Herrings	11.6	4.0	850
Other fish, fresh	10.0	1.0	500
Shell fish (without shell)	5.0	1.5	350
Canned and salted fish	20.6	10.3	1,800

Commodity.	Protein. %	Fat. %	Energy value per kilo. Calories.
Dairy Produce—			
Milk	3.3	3.7	700
Butter	1.0	85.0	7,950
Cheese (United States and United Kingdom)	25.0	30.0	4,000
Cheese (France and Italy)	25.0	29.0	3,700
Condensed milk, unsweetened	9.6	9.3	1,700
Condensed milk, sweetened	8.8	8.3	3,300
Margarine	1.2	83.5	7,800
Lard	2.2	94.0	8,800
Fruit—			
Apples	0.3	0.3	480
Bananas	0.7	0.4	600
Oranges	—	—	350
Nuts	6.5	22.8	2,600
Fruits, fresh	0.7	0.4	500
Fruits, preserved (without sugar)	2.0	2.0	2,800
Vegetables—			
Chestnuts	—	—	2,000
Potatoes	1.8	0.1	700
Beans, Peas and Lentils (dried)	24.3	1.3	3,600
Green Peas and Broad Beans (shelled)	7.0	0.5	1,000
Other vegetables	0.75	0.15	200
Preserved vegetables (bottled and canned)	1.5	0.3	380
Sugar, Cocoa, etc.—			
Cocoa (and chocolate)	15.0	34.0	4,800
Sugar (taken as refined)	—	—	4,100
Molasses	1.0	—	2,300
Glucose, solid	—	—	3,400
Glucose, liquid	—	—	3,200
Olive Oil (refined)	—	100.0	9,300

[One kilo corresponds to about two and one-quarter pounds.]

Dr. Funk's Classification of the Vitamines

Antirachitic (fat-soluble A) vitamine. Animals that can be used for experimental purposes: rats and dogs (puppies). The disease can be induced in these animals by feeding them with a synthetic diet in which the fat consists of lard. The animals can be cured of rickets by adding butter fat, codliver oil, or extracts of green vegetables to the diet.*

Antineuritic (water-soluble B) vitamine. For experimental purposes pigeons, and fowls in general, and rats can be used. The disease may be developed with polished rice. Beriberi may be cured with yeast, etc.

Antiscorbutic (water-soluble C) vitamine. Guinea-pigs and monkeys are used. The disease may be developed with oats and autoclaved milk. The curative agent for scurvy is orange juice, or tomatoes, etc.

* Professor Mendel writes to say that "you are going beyond dependable knowledge in this paragraph." This is Dr. Funk's classification, not mine. The discussion in Chapter XII clearly demonstrates that I have not overlooked alternative hypotheses.

PROTEINS. COMPOSITION

Per Cent. of Amino-Acids Isolated from Various Proteins

	Gliadin—Rye	Gliadin—Wheat	Hordein—Barley	Zein—Maize	Legumin—Vetch	Legumin—Cow pea	Salmin—Salmon	Edestin—Hemp	Excelsin—Brazil nut	Keratin—Sheep's horn	Squash seed—Globulin	Amandin—Almond
Glycocoll	0.13	0.02	0.00	0.00	0.39	0.38	0.00	3.80	0.60	0.45	0.57	0.51
Alanine	1.33	2.00	0.43	9.79	1.15	2.08	0.00	3.60	2.33	1.6	1.92	1.40
Valine	?	0.21	0.13	1.88	1.36	?	4.3	6.20	1.51	4.5	0.26	0.16
Leucine	6.30	5.61	5.67	19.55	8.80	8.00	0.00	14.50	8.70	15.3	7.32	4.45
Proline	9.82	7.06	13.73	9.04	4.04	3.22	11.0	4.10	3.65	3.7	2.82	2.44
Phenylalanine .	2.70	2.35	5.03	6.55	2.87	3.75	0.0	3.09	3.55	1.9	3.32	2.53
Aspartic acid..	0.25	0.58	Not found	1.71	3.21	5.30	0.0	4.50	3.85	2.5	3.30	5.42
Glutamic acid..	37.8	42.98	43.19	26.17	18.30	16.97	0.0	18.84	12.94	17.2	12.35	23.14
Serine	0.06	0.13	?	1.02	?	0.53	7.8	0.33	0.0	1.1	?	?
Cystine	?	0.45	?	?	Undet.	Undet.	0.0	1.00	?	7.5	0.23	?
Tyrosine	1.19	1.20	1.67	3.55	2.42	1.55	0.0	2.13	3.03	3.6	3.07	1.12
Arginine	2.22	3.15	2.16	1.55	11.06	11.71	87.4	14.17	14.14	2.7	14.44	11.85
Histidine	0.39	0.61	1.28	0.43	2.94	1.69	0.0	2.19	1.47	?	2.63	1.58
Lysine	0.00	0.00	0.00	0.00	3.99	4.98	0.0	1.65	1.64	0.2	1.99	0.70
Ammonia	5.11	5.11	4.87	3.64	2.12	2.05		2.28	1.80	?	1.55	3.70
Tryptophane ..	Pres.	Pres.	Pres.	0.00	Pres.	Pres.	0.0	Pres.	Pres.		Pres.	Pres.
Total	68.31	71.46	78.16	85.27	62.65	62.22	110.5	82.38	60.21		55.77	59.00

PROTEINS. COMPOSITION

Per Cent. of Amino-Acids Isolated from Various Proteins

	Ovalbumin—Cryst.	Vitellin—Hen's egg	Muscle—Scallop	Cocoon—Œceticus palensis	Indian Tussa silk	Italian Silk cocoons	Japanese Silk cocoons	Globin—Horse hæmoglobin	Gelatin	Casein—Cow	Elastin	Histone—Thymus
Glycocoll	0.00	0.00	0.00	27.19	1.5	33.59	35.00	0.00	16.5	0.00	25.75	0.5
Alanine	2.22	0.75	....	18.8	9.8	20.00	22.6	4.2	0.8	1.5	6.58	3.46
Valine	2.50	1.87	....	—	—	—	—	....	1.0	7.2	1.4	....
Leucine	10.71	9.87	8.78	0.75	4.8	0.75	0.7	29.0	2.1	9.4	21.38	11.80
Proline	3.56	4.18	2.28	3.2	3.0	0.8	0.7	2.3	5.2	6.7	1.74	1.46
Phenylalanine .	5.07	2.54	4.90	1.8	0.3	1.2	1.3	4.2	0.4	3.2	3.89	2.20
Aspartic acid..	2.20	2.13	3.47	0.25	2.8	1.0	1.3	4.4	0.56	1.4	....	....
Glutamic acid..	9.10	12.95	14.88	2.35	1.8	0.25	0.07	1.7	1.88	15.55	0.76	3.63
Serine	?	?	....		5.4	1.9		0.6	0.4	0.5	....	....
Cystine	?	?	....					0.3	0.0	0.07	?	
Tyrosine	1.77	3.37	1.95	0.00	1.0	9.0	9.7	1.3	0.00	4.5		5.2
Arginine	4.91	7.46	7.38					5.4	7.62	4.84	0.3	15.5
Histidine	1.71	1.90	2.02					11.0	0.4	2.59		1.5
Lysine	3.76	4.81	5.77					4.3	2.75	5.95		6.9
Ammonia	1.34	1.25	1.08							1.61		
Tryptophane ..			Pres.					Pres.	0.0	1.5		
Total	50.08	54.02	52.51									

[From A. P. Mathews' *Physiological Chemistry* (Wm. Wood & Co.)]

THE DISTRIBUTION OF THE THREE ACCESSORY FACTORS IN THE COMMONER FOODSTUFFS

(Compiled by the *British Medical Research Committee*)

Classes of foodstuff	*Fat-soluble A or anti-rachitic factor*	*Water-soluble B or anti-neuritic (anti-beriberi) factor*	*Anti-scorbutic factor*
Fats and oils.			
Butter	+ + +	0	
Cream	+ +	0	
Codliver oil	+ + +	0	
Mutton fat	+ +		
Beef fat or suet	+ +		
Peanut or arachis oil	+		
Lard	0		
Olive oil	0		
Cottonseed oil	0		
Coconut oil	0		
Cocoa butter	0		
Linseed oil	0		
Fish oil, whale oil, herring oil, &c.	+ +		
Hardened fats, animal or veg. origin	0		
Margarine prepared from animal fat	Value in proportion to amount of animal fat contained		
Margarine from vegetable fats or lard	0		
Nut butters	+		
Meat, fish, &c.			
Lean meat (beef, mutton, &c.)	+	+	+
Liver	+ +	+ +	+
Kidneys	+ +	+	

Classes of foodstuff	*Fat-soluble A or anti-rachitic factor*	*Water-soluble B or anti-neuritic (anti-beriberi) factor*	*Anti-scorbutic factor*
Meat, fish, &c.—Cont.			
Heart	+ +	+	
Brain	+	+ +	
Sweetbreads	+	+ +	
Fish, white	0	very slight, if any	
" fat (salmon, herring, &c.)	+ +	"	
" roe	+	+ +	
Tinned meats	?	very slight	0
Milk, cheese, &c.			
Milk, cow's, whole, raw	+ +	+	+
" skim "	0	+	+
" dried whole	less than + +	+	less than +
" boiled "	Undetermined	+	"
" Condensed, sweetened	+	+	"
Cheese, whole milk	+		
" skim	0		
Eggs.			
Fresh	+ +	+ + +	? 0
Dried	+ +	+ + +	? 0
Cereals, pulses, &c.			
Wheat, maize, rice, whole grain	+	+	0
Wheat, germ	+ +	+ + +	0
" maize, bran	0	+ +	0
White wheaten flour, pure cornflour, polished rice, &c.	0	0	0
Custard powders, egg substitutes, prepared from cereal products	0	0	0
Linseed, millet	+ +	+ +	0
Dried peas, lentils, &c.		+ +	0
Peaflour (kilned)		0	0
Soy beans, haricot beans	+	+ +	0
Germinated pulses or cereals	+	+ +	+ +

Classes of foodstuff	*Fat-soluble A or anti-rachitic factor*	*Water-soluble B or anti-neuritic (anti-beriberi) factor*	*Anti-scorbutic factor*
Vegetables and fruits			
Cabbage, fresh	+ +	+	+ + +
" " cooked		+	+
" dried	+	+	very slight
" canned			"
Swede, raw expressed juice			+ + +
Lettuce	+ +	+	
Spinach (dried)	+ +	+	
Carrots, fresh raw	+	+	+
" dried	very slight		
Beetroot, raw, expressed juice			less than +
Potatoes, raw	+	+	
" cooked			+
Beans, fresh, scarlet runners, raw			+ +
Onions, cooked			+ (at least)
Lemon juice, fresh			+ + +
" preserved			+ +
Lime juice, fresh			+ +
" preserved			very slight
Orange juice, fresh			+ + +
Raspberries			+ +
Apples			+
Bananas	+	+	very slight
Tomatoes (canned)			+ +
Nuts	+	+ +	
Miscellaneous			
Yeast, dried		+ + +	
" extract and autolyzed	?	+ + +	0
Meat extract	0	0	0
Malt extract		+ in some specimens	
Beer		0	0

[*The following memorandum was issued by the British Committee on Accessory Food Factors in June,* 1919]

SOME FACTS CONCERNING NUTRITION, FOR THE GUIDANCE OF THOSE ENGAGED IN ADMINISTRATION OF FOOD RELIEF TO FAMINE-STRICKEN DISTRICTS

Recent research has shown that the requirements of the human organism as regards diet cannot be met entirely by an adequate supply of protein, fat, carbohydrate, inorganic salts, and water. It has therefore modified the common belief of ten or more years ago, when the attention of physiologists was focused upon the calorie or energy value of the diet. It is now established that, in addition to these necessary constituents, certain unidentified principles, known as accessory food factors or "vitamines," must also be present in order to maintain health and prevent the occurrence of "deficiency diseases." These substances have not so far been isolated, little is known of their chemical or physical properties, and at the present time their presence can only be detected by experiments with animals.

These accessory factors or vitamines are widely distributed among naturally occurring foodstuffs, and in time of peace, under normal conditions of food supply, the variety of food consumed by Eu-

ropean nations protects them from risk of any deficiency in these essential substances. Under the conditions arising from the war a different state of things exists; in addition to a general shortage of food there is also a great restriction in the variety available, and danger from "deficiency diseases" is to be feared.

Of these diseases scurvy is the best known, and the belief that it is caused by some deficiency in the diet has long been strongly held. Recent research has added to the deficiency diseases beriberi, rickets, and other less well-marked disorders of growth and departures from health.

The following notes have been compiled by the Committee on Accessory Food Factors in the hope that they may afford practical help to those occupied in the administration of food relief to the famine districts of Eastern Europe. The advice given is based upon the present state of our knowledge of the distribution of accessory food factors (vitamines) in natural foodstuffs and of the rôle played by them in preventing disease and in promoting health and growth.

The accessory food factors at present recognized are three in number:

(1) Antineuritic or antiberiberi factor, identified with the water-soluble B growth factor of the American investigators.

(2) Fat-soluble A growth factor or antirachitic factor.

(3) Antiscorbutic factor.

As far as is known the accessory food factors can-

not be produced by the animal organism, and all animals are dependent for their supply directly or indirectly upon the plant kingdom.

DISTRIBUTION AND PROPERTIES OF THE ACCESSORY FACTORS

(1) *Antineuritic or Antiberiberi Factor* ("water-soluble B" growth factor of the Americans).

This vitamine prevents the occurrence of beriberi in man and analogous diseases in animals. It is also necessary to promote satisfactory growth in young animals. It is widespread, and is found to some extent in almost all natural foodstuffs. *Its principal sources are the seeds of plants and the eggs of animals,* where it is deposited, apparently, as a reserve for the nutrition of the young offspring. Highly cellular organs such as the liver and the brain contain considerable amounts of this vitamine; flesh contains comparatively little. Yeast cells are a rich source, so also are yeast extracts, e.g., "marmite." In the case of peas, beans, and other pulses, this vitamine is distributed throughout the seed, but with cereals it is concentrated in the germ (embryo) and in the peripheral layer of the seed which in milling is peeled off with the pericarp and forms the bran.

Beriberi is occasioned by a diet composed too exclusively of cereals from which germ and bran have been removed by milling, as in the case of polished rice or white wheat flour. The disease is common

where polished rice is the staple article of diet to the almost entire exclusion of other foodstuffs. It is rare, though not unknown, where white wheat bread is eaten, because the consumption of this type of cereal food is usually accompanied by a sufficiency of other foodstuffs containing the essential principle. It is unknown where rye bread is the staple food, because in the milling of rye there is no separation of the germ.

(2) *The Fat-Soluble A Growth Factor or Antirachitic Factor, necessary to promote Growth and prevent Rickets in young Animals.*

This vitamine appears to be necessary also to maintain health in adults, and it has been suggested that war edema may be due to a lack of this factor in the diet.

The main sources of this factor are two in number:

(1) certain fats of animal origin,

(2) green leaves.

The most notable deposits of this factor are in cream, butter, beef fat, fish oils (for example, cod-liver oil, whale oil), egg yolk. It is present in very small or negligible amount in lard (pig fat) and in vegetable oils, as, for example, linseed oil, olive oil, cottonseed oil, coconut oil, palm oil; peanut or arachis oil is reported to contain it in larger amount. It will be noticed that this factor is found chiefly in the more expensive fats.

While green-leaf vegetables contain the fat-soluble factor, root vegetables are deficient in it; war

edema has been frequently reported under circumstances in which root vegetables have formed a large proportion of the diet.

(3) *Antiscorbutic Factor.* This vitamine is necessary in a diet for the prevention of scurvy, and is found in fresh vegetable tissues and (to a much less extent) in fresh animal tissues. Its richest sources are such vegetables as cabbage, swedes, turnips, lettuce, watercress, and such fruits as lemons, oranges, raspberries, tomatoes. Inferior in value are potatoes, carrots, French beans, scarlet runners, beetroot, mangolds, and also (contrary to popular belief) lime juice. Potatoes, although classed among the less valuable vegetables as regards antiscorbutic value, are probably responsible for the prevention of scurvy in northern countries during the winter, owing to the large quantities which are regularly consumed.

Milk and meat possess a definite but low antiscorbutic value.

This vitamine suffers destruction when the fresh foodstuffs containing it are subjected to heat, drying, or other methods of preservation.

All dry foodstuffs are deficient in antiscorbutic properties—such are cereals, pulses, dried vegetables, and dried milk.

Tinned vegetables and tinned meat are also deficient in antiscorbutic principle. In case of tinned fruits the acidity of the fruit increases the stability of the vitamine, and prevents, to some extent, the destruction which would otherwise occur dur-

ing the sterilization by heat and the subsequent storage.

Practical Application of the Foregoing Facts to the Prevention of Disease

(1) *Prevention of Beriberi*

It is unlikely that any danger of beriberi will arise among the famine-threatened districts of Eastern Europe *as long as wholemeal flour from rye, wheat, barley, maize, or peas, beans, and lentils are provided.* Mere shortage of food does not cause beriberi, and poverty ensures that the whole grain is consumed for purposes of economy.

(2) *Prevention and Cure of Rickets or Growth Failure in Children or War Edema in Adults*

Evidence is accumulating that rickets is caused by a shortage not of fat as such, but of the "fat-soluble growth factor" which is contained in certain fats. Xerophthalmia, a severe disease of the external eye, leading, if untreated, to blindness, has also been attributed to lack of this factor. Infants and young children must therefore be supplied with the *right kind of fat.* To prevent rickets (1) full cream milk should be secured for artificially fed infants when possible; failing that, (2) full cream dried milk or (3) full cream unsweetened condensed milk. (2) is preferred to (3), and, in case of ignorant or careless mothers, even to (1), in or-

der to prevent spread of infection and intestinal disorders. In all cases where (2) or (3) are used, an extra antiscorbutic should be given (see below).

Sweetened condensed milk is undesirable for the reason that the degree of dilution required by the high sugar content renders the food, as prepared, deficient in the fat-soluble (antirachitic) factor as well as in fat and protein.

Milk and butter are the best sources of the antirachitic (or fat-soluble) factor for young and growing children; margarines made from animal fats are also valuable; those made from vegetable oils are to be condemned. If there is a shortage of butter it should be reserved for children, but if totally lacking the deficiency can be replaced by codliver oil and other fish oils, or by eggs. If all animal fats are unavailable, peanut oil should be selected in preference to other vegetable oils for preparation of margarines, etc., and some effort should be made to utilize the fat-soluble vitamine contained in green leaves.

Green leaves are a cheap and readily available source of the fat-soluble vitamine, and adults can probably maintain good health when animal fats are substituted by vegetable fats if green-leaf vegetables are consumed in fair quantity. In case of this vitamine, the loss involved in ordinary cooking is not serious. Unfortunately infants or very young children cannot take green vegetables in the ordinary way, but the juices expressed from cabbages and other green-leaf vegetables, raw or even

after steaming (not immersing in boiling water) for a few minutes, might be given even to infants if all other sources of this most necessary vitamine have failed.

Purées, carefully prepared from cooked spinach or lettuce, can be tolerated in small quantities (one teaspoonful daily) by many young infants, and the amount taken can be increased regularly with age.

In cases where rickets or growth failure or xerophthalmia are already well established, a daily dose of codliver oil is essential in addition to all other procedure.

Pregnant and nursing mothers should have as liberal a supply of the fat-soluble factor as is possible. Rickets is not confined to artificially fed children. Breast-fed children depend for an adequate supply of this factor on the milk, which in turn depends upon the diet of the mother.

(3) *Prevention of Scurvy*

Use of germinated seeds. If fresh vegetables or fruit are scarce or absent an antiscorbutic food can be prepared by moistening any available seeds (wheat, barley, rye, peas, beans, lentils) and allowing them to germinate. It is necessary, of course, that these should be in the natural whole condition, not milled or split. The seeds should be soaked in water for 24 hours, and kept moist with access of air for 1–3 days, by which time they will have sprouted. This sprouted material possesses an antiscorbutic value equal to that of many fresh vege-

tables, and should be cooked in the ordinary way for as short a time as possible.

In case of shortage it should be remembered that salads are of more value than cooked vegetables. The extent to which the antiscorbutic factor is destroyed during cooking depends chiefly upon the time employed. When supplies are limited vegetables should be cooked separately and for as short a time as possible; they should not be cooked for long periods with meat in soups or stews.

Preserved foods, with a few exceptions, may be regarded as devoid of the antiscorbutic principle. Lemon juice retains some value in this respect; canned tomatoes (and presumably other tinned acid fruits) have also antiscorbutic value. *Canned vegetables are useless for prevention of scurvy, as also are dried vegetables.*

Infantile scurvy must be considered separately as many of the above foodstuffs are unsuited to infants or young children. To avert danger all artificially nourished infants should receive an extra antiscorbutic. Cow's milk, even when raw, is not rich in the antiscorbutic vitamine; when heated, dried, or preserved, the amount contained is still further reduced. The most suitable antiscorbutic material to use is fresh orange juice, 1-3 or 4 teaspoonfuls (5-15 c.c.) daily, according to age. Raw swede (or, if unavailable, turnip) juice is a potent antiscorbutic, and an excellent substitute for orange juice; to obtain the juice the clean-cut surface is grated on an ordinary kitchen grater and the pulp obtained is squeezed in muslin. Tomato juice, even from

canned tomatoes, and grape juice can also be used; the latter is, however, less potent than orange juice, and a larger dose should be given.

Pregnant and nursing mothers. If babies are breast fed it is important that the pregnant and nursing mother should receive an adequate supply of antiscorbutic food in her diet. The popular belief that green vegetables are harmful in such cases is often without foundation. Infantile scurvy is not unknown in breast-fed children.

It is evident that many of the above deficiency diseases are rife among the populations of Central and Eastern Europe. It is essential, therefore, that the principles set forth in the preceding paragraphs should be fully understood by all persons engaged in administering relief to these districts.

Signed on behalf of the Committee,

F. G. HOPKINS, *Chairman.*

HARRIETTE CHICK, *Secretary.*

June, 1919.

REFERENCES

Calories. The general subject of calories is treated in all text-books of physics. For an admirable and at the same time elementary treatment, R. A. Millican and H. G. Gale's *Practical Physics* (Ginn & Co., New York, 1920), Chapter 9, is strongly recommended. The application of calories to food chemistry and physiology is brought out by H. C. Sherman: *Chemistry of Food and Nutrition* (Macmillan & Co., New York, 1918), chapter 6, and W. H. Howells: *A Text-Book of Physiology* (W. B. Saunders, Philadelphia, 1920), chapter 51. Lavoisier's pioneer work is discussed by T. M. Lowry in his *Historical Introduction to Chemistry* (Macmillan & Co., London, 1915), page 385, and by M. M. Pattison Muir in his *Heroes of Science* (*Chemists*) (Society for Promoting Christian Knowledge, London, 1883).

In this country Dr. F. G. Benedict is the foremost investigator of methods for measuring muscular activity. See for example his paper on "Muscular Work. A Metabolic Study with Special Reference to the Efficiency of the Human Body as a Machine," published by the Carnegie Institute of Washington, No. 187 (1913).

Proteins, fats and carbohydrates. A very elementary treatment of the three classes of foodstuffs may be found in W. M. Bayliss' *The Physiology of Food and Economy in Diet* (Longmans, Green & Co., 1917), chapters 3 and 4. H. C. Sherman's *Food Products* (Macmillan & Co., 1915), chapter 1, may also be consulted. An account of the foodstuffs may be found in all text-books of physiology and physiological chemistry; for example, G. N. Stewart: *A Manual of Physiology* (William Wood & Co., New York, 1917), chapter 7.

Inorganic salts, water, condiments, flavors, etc. These are excellently discussed in Howell's Physiology (see above), chapter 49. See also Osborne and Mendel's paper: "Inorganic Elements of Nutrition." *The Journal of Biological Chemistry,* volume 34, page 131, 1918. For those who are accustomed to scientific literature, the chapter on "Water, Its Properties and Functions" in W. M. Bayliss' *Principle of General Physiology* (Longmans, Green & Co., London, 1915), page 226, is one I would strongly recommend. It is the best account of all I have ever read.

Amino-acids. The standard volume on this subject is F. P. Underhill's *The Physiology of the Amino-acids* (Yale University Press, New Haven, 1915). Professor Mendel has well summarized his and Dr. Osborne's researches in a lecture on "Nutrition and Growth" which he delivered before the

members of the Harvey Society of New York, which was printed in the *Journal of the American Medical Association*, May 8, 1915, page 1539. An abridged account of Drs. Osborne and Mendel's work may also be found in H. C. Sherman's *Chemistry of Food and Nutrition* (see above), page 62.

Vitamines *

General summary. A very complete report, giving full references to individual papers, is the one prepared by the British Medical Research Committee (Special Report Series, No. 38, London, 1919). E. V. McCollum's *The Newer Knowledge of Nutrition* (Macmillan & Co., New York, 1918) gives an exhaustive account of the author's researches. For a further summary of Dr. McCollum's work the reader is referred to his articles in the *Journal of the American Medical Association*, May 12, 1917, page 1379, and September 21, 1918, page 937. Graham Lusk in his *The Elements of the Science of Nutrition* (W. B. Saunders & Co., Philadelphia, 1917) devotes a chapter (13) to the subject. Another summary on vitamines is given in a paper by Katherine Blunt and Chi Che Wang in the *Journal of Home Economics*, January, 1920, page 1. Those possessing a knowledge of German should consult Dr. Funk's exhaustive review in the *Ergebnisse der Physiologie*, volume 13, page 125,

* The references do not pretend to be complete, but they rather aim to present the reader with a representative list. Those desiring the complete list may consult the papers quoted under "General Summary."

1913. This article contains references to all the earlier literature. The rôle played by vitamines in clinical medicine is discussed by F. G. Hopkins, Sir James Barr, etc., in the *British Medical Journal,* page 147, 1920.

Historical. The necessary historical setting is to be found in the paper by T. B. Osborne and L. B. Mendel, published by the Carnegie Institute of Washington, 1911, No. 156, parts 1 and 2. An account of F. G. Hopkins' pioneer researches may be found in the *Analyst,* volume 31, page 395, 1906; the *Journal of Physiology,* volume 44, page 425, 1912; and the *Biochemical Journal,* volume 15, page 167, 1913.

Fat-soluble A vitamine. The earlier papers dealing with the value of butter fat versus lard are by E. V. McCollum and M. Davies, and T. B. Osborne and L. B. Mendel, and are printed in the *Journal of Biological Chemistry,* volume 15, pages 167 and 311, 1913, and volume 16, page 423, 1913. The very latest papers—November, 1920—are by J. C. Drummond and K. H. Coward in the *Biochemical Journal,* volume 14, pages 661 and 668, 1920. The possible relationship of this vitamine to the carotinoid pigment—one constantly associated with the chlorophyll of plants—is discussed by Steenbock in the *Journal of Biological Chemistry,* volume 41, page 81, 1920, and by L. S. Palmer, *Science,* volume 50, page 501, 1919. M. Stephenson and A. B. Clark, in their paper in the *Biochemical Journal,* volume 14, page 502, 1920, discuss the eye disease, xerophthalmia, and its possible relationship to the pres-

ence in the diet of insufficient quantities of fat-soluble A. Xerophthalmia is also discussed in the earlier papers by McCollum (see above).

Two distinct vitamines, fat-soluble A and water-soluble B. The proof that there exists more than one type of vitamine was first shown by E. V. McCollum and M. Davies, *Journal of Biological Chemistry,* volume 23, page 181, 1915.

The effect of heat. See, among others, H. Steenbock, *Journal of Biological Chemistry,* volume 35, page 577, 1918.

Beriberi. The story up to 1913 is discussed by E. P. Vedder in book on beriberi. C. Eijkman's classical paper appeared in the *Archiv für pathologische Anatomie,* volume 149, page 197, 1897. Scarcely less important are the papers by Funk and co-workers (*Journal of State Medicine,* June, 1912, page 1; *Lancet,* page 1266, 1911; *Journal of Physiology,* volume 43, page 395, 1911; *Biochemical Journal,* volume 8, page 598, 1914). See also the papers by W. P. Chamberlain and others, *Philippine Journal,* volume 6, number 3, section B, medical sciences, June, 1911, page 177; A. Harden and S. S. Zilva, *Biochemical Journal,* volume 11, page 172, 1917; H. Chick and E. M. Hume, *Proceedings of the Royal Society,* section B, volume 60, 1917; A. R. Leggale, *Edinburgh Journal of Medicine,* volume 24, page 32, 1920; and A. D. Emmet and G. O. Luros, *Journal of Biological Chemistry,* volume 43, pages 265 and 287, 1920.

Scurvy. An exhaustive treatise is the very recent publication of A. F. Hess: *Scurvy Past and*

Present (J. B. Lippincott Co., Philadelphia. 1920). In this country Drs. McCollum and Hess have done much experimental work on scurvy. Dr. McCollum's papers are included in those quoted under "Summary." A summary of Dr. Hess's researches is given in the *Journal of the American Medical Association,* September 21, 1918, page 941. Among English investigators, Drs. Harden and Chick stand out prominently. Accounts of their work may be found in the *Biochemical Journal,* volume 12, pages 131 and 270, 1918, and volume 13, page 199, 1919. The effect of heat on the water-soluble C vitamine is discussed by E. M. Delf and R. F. Skelton in the *Biochemical Journal,* volume 12, page 448, 1918. A useful survey is that drawn up by the food (war) committee of the Royal Society, published in *Lancet,* Nov. 30, 1919, page 756.

Rickets. Early suggestions that rickets might be due to a deficiency in the vitamine content of the food consumed were made by Hopkins (*Analyst,* volume 31, page 395, 1906) and Funk (*Die Vitamine,* 1914). The papers by McCollum,, Osborne and Mendel quoted above discuss the fat-soluble A vitamine, particularly in reference to the eye disease xerophthalmia. Much of the clinical work in this country has been done by Hess and co-workers (*Journal of the American Medical Association,* page 1583, 1917; page 900, 1918, and page 218, 1920). In England Dr. Mellanby has been an active worker (see *Lancet,* March 15, 1919, page 407).

Pellagra. The most important work on this subject is by Dr. Goldberger and his associates (see

the Washington *Public Health Reports,* volume 31, page 3159, 1916, volume 33, page 481, 1918; *Journal of the American Medical Association,* page 944, 1918; and *Archives of Internal Medicine,* volume 25, page 421, 1920). Historically, the paper by Funk (*Journal of Tropical Medicine,* volume 6, page 166, 1913) is of extreme interest. Dr. McCollum's contributions should also be consulted (*Journal of Biological Chemistry,* volume 32, pages 29, 171 and 347, 1917; volume 30, page 13, 1917; and the *American Journal of Physiology,* volume 41, pages 333 and 361, 1917).

The nursing mother. Infant feeding. Consult J. L. Morse and F. B. Talbot: *Diseases of Nutrition and Infant Feeding* (Macmillan & Co., New York, 1920). The scarcity of the antiscorbutic factor in milk is discussed by Hess and Fish, *American Journal of Diseases of Children,* volume 8, page 385, 1914; and by Chick and Hume, *Biochemical Journal,* volume 12, page 131, 1918. See also the excellent pamphlet distributed by the Connecticut Agricultural Experiment Station, New Haven, Conn., entitled *The Food Value of Milk* (prepared by E. L. Ferry. Bulletin 215, December, 1919). The London Local Government Food Reports discuss dried milk in infant feeding (report No. 24, 1918) and proprietary infants' food (report No. 20, 1914). The value of dried milk is also the subject of critical comment in an article by E. M. Hume and R. S. Barnes, *Biochemical Journal,* volume 13, page 306, 1919. See also the article by Dr. W. N. Bradley on Feeding the New-born (*Archives of Pediatrics,* vol-

ume 37, page 144, 1920); and the discussion by Dr. Mellanby and others (*Proceedings of the Royal Society of Medicine,* volume 13, section of diseases of children, page 77, 1920).

Vitamine content of different foods. The table given on page 191 of this book should prove useful. The article by M. Davies and collaborators (*Journal of Home Economics,* volume 12, page 207, 1920) should also be consulted. Attempts at quantitative estimations are discussed in the paper by W. H. Eddy and H. C. Stevenson, *Journal of Biological Chemistry,* volume 43, page 295, 1920.

Nomenclature. The suggestion that "vitam*in*" be substituted for "vitam*ine*," because the ending "in," according to the English Chemical Society, represents a neutral substance of unidentified composition, whereas the "ine" terminology is associated with a group of well-known organic substances, is made by J. C. Drummond, *Biochemical Journal,* volume 14, page 660, 1920.

Clinical Symptoms. The clinical symptoms of the various diseases discussed in this book are described in various books dealing with the practice of medicine. One of the best known of these is Sir William Osler's *The Principles and Practice of Medicine* (D. Appleton & Co., New York, 1920).

Miscellaneous. McCollum and Simmonds: *The American Home Diet* (Frederick C. Mathews Co., Detroit, 1920).

Vernon Kellog and A. E. Taylor: *The Food Problem* (Macmillan & Co., New York, 1917).

Graham Lusk: *The Fundamental Basis of Nutrition* (Yale University Press, New Haven, 1915).

J. R. Smith: *The World's Food Resources* (Henry Holt & Co., New York, 1919).

E. H. Starling: *The Feeding of Nations* (Longmans, Green & Co., London, 1919).

L. J. Henderson: *The Fitness of the Environment* (Macmillan & Co., New York, 1913).

A. W. McCann: *The Famishing World* (George H. Doran & Co., New York, 1918).

H. D. Chapin: "How the Pediatric Teaching of Nutrition May Affect the Nation's Welfare." *Journal of the American Medical Association,* August 7, 1920, page 364.

W. A. Brown: "A Study of the Malnutrition Among School Children." *Journal of the American Medical Association,* July 3, 1920, page 27.

H. C. Sherman: "Food Chemistry in the Service of Human Nutrition." *Journal of Industrial and Engineering Chemistry,* May, 1918, page 383.

J. R. Murlin: "Diet of the United States Army Soldiers." *Journal of the American Medical Association,* September 21, 1918, page 950.

Paul Roth: "The Civilian War Ration." *Journal of the American Medical Association,* September 21, 1918, page 952.

H. E. Dubin and M. J. Lewi: "The Preparation of a Stable Vitamine Product and Its Value in Nutrition." *American Journal of Medical Sciences,* February, 1920, page 1.

M. T. Wellman: "Recent Advances in Our Knowledge of Food Selection and Preparation."

Journal of Home Economics, January, 1920, page 15.

J. R. Murlin: "What We Have Learnt in Dietetics in the Army." *Journal of Home Economics,* March, 1920, page 97.

Chi Che Wang: "Is the Chinese Diet Adequate?" *Journal of Home Economics,* July, 1920, page 289.

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